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FOURTH SERIES.

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WITH PLATES I–VIII.

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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*Observations on the Genus Romingeria;* by CHARLES E. BEECHER. (With Plates I–V.)

Introduction.

THE type species of the genus *Romingeria* (*R. umbellifera* Billings) has been known since 1859, but on account of its rarity and fragmentary occurrence it has failed to attract more than casual attention. In many ways the genus should be considered as one of the most interesting and remarkable of fossil corals. Several large and well-preserved colonies, recently found by the writer in the Corniferous limestone near Leroy, New York, emphasize the importance of reviewing the characters of the type, especially since it has been confused with other species and also because some details not hitherto observed are now to be noted.

Eight species have at various times been referred to *Romingeria*, mostly upon very insufficient grounds; hence the original conception of the genus has become obscured and is without much present significance. If the original description and figure of Billings be taken as a starting point, the subsequent vicissitudes of this genotype will be appreciated.

In 1859, Billings[1] described three species of *Aulopora*,—*A. cornuta*, *A. filiformis*, and *A. umbellifera*. The original diagnosis of the latter is reproduced herewith:

"AULOPORA UMBELLIFERA (Billings).

"The mode of growth of this remarkable species is sufficient to distinguish it at once from all other described forms of the *genus*. The parent stems are about one line in diameter, and remain single and straight for the distance of one fourth, or half an inch, when they give off branches in all directions, sometimes ten or twelve at once. These are at first oblique or somewhat parallel with the main tube, and are connected laterally; they then radiate like the spokes of a wheel, at right

angles to the parent corallites, each soon giving birth to a similar circlet of new tubes.

"It may be that this species should constitute a new *genus;* but as I have not been able to ascertain wherein its internal structure differs from *Aulopora*, I have disposed of it as above, provisionally.

"*Locality and formation.*—Lot 6, con. 1, Wainfleet. Corniferous."

Rominger,[3] in 1876, was the first to adopt the suggestion of Billings as to the generic import of *A. umbellifera.* He showed its distinct value, and proposed the genus *Quenstedtia*, with this species as the type. Under it he considered *A. cornuta* Billings, as consisting of fragments of *A. umbellifera* Billings, in which only from one to three branches or buds are given off. The species *Q. niagarensis* was also defined by Rominger at the same time.

Three years later (1879) Nicholson published his general work on the "Tabulate Corals,"[4] and substituted the name *Romingeria* for *Quenstedtia*, which proved to be preoccupied. No change was made by Nicholson in the specific synonymy, and the identity of *A. umbellifera* and *A. cornuta* was accepted by him, though in his description of *R. umbellifera* he includes characters never present in what the writer believes to be Billings's species *sensu strictu.* His illustration especially resembles that given by Billings for his *A. cornuta*, though the statement is made that there were specimens in his hands apparently belonging to *A. cornuta* and agreeing with *Aulopora* proper rather than with *Romingeria.* However, as Nicholson's redescription of *R. umbellifera* seems to be based largely on his own material, as represented in his figures, it appears highly probable that the generic reference to *Romingeria* was correct. The discrepancies between his description and what is now believed to clearly represent the original species, can be best explained on the supposition that Nicholson did not have true *R. umbellifera*, but did have representatives of what is apparently a distinct, though allied, species of *Romingeria*, which is not uncommon in the Upper Helderberg limestones at the Falls of the Ohio and elsewhere, and is the form commonly, though erroneously, identified with *R. umbellifera.*

Davis,[4] in the volume of plates illustrating Kentucky fossil corals, dated 1885* (though apparently not published before

* This volume bears the title of "Kentucky Fossil Corals. A Monograph of the Fossil Corals of the Silurian and Devonian Rocks of Kentucky. By William J. Davis. [In Two Parts. Part II.] Frankfort, Kentucky, 1885. Copyrighted 1887." This "monograph," or more properly an illustrated catalogue, as it has proved to be, consists of a letter of transmittal and thirteen pages of index to the plates. The plates and explanations number one

1887), figures a species of *Romingeria* which he identifies with *R. umbellifera*. Through the kindness of Professor R. T. Jackson, the writer has been enabled to study the original specimens in the Davis collection now in the Museum of Comparative Zoology, and they prove not to be typical of that species but of the form previously mentioned as generally referred to it. Davis also applies four new specific names in connection with *Romingeria*. The original examples of three of the species appear not to be congeneric, while the fourth is a *Romingeria*.

In a revision of the Canadian paleozoic corals, published by Lambe in 1899,[8] there is included under *Romingeria* the single species *R. umbellifera* Billings, sp. A reëxamination of the type showed the presence of mural pores, together with the convex tabulæ. No septal spines were observed.

To review briefly the history and synonymy of the genotype of *Romingeria*, it may be stated that in 1859 Billings described the species *Aulopora umbellifera*. This was made the type of *Quenstedtia* by Rominger in 1876, who also considered *A. cornuta* Billings as synonymous. On account of this generic name having been used previously, Nicholson, in 1879, substituted *Romingeria*. His description was apparently founded upon two species, *R. umbellifera* and *R.* sp., the latter being the one illustrated by him. Davis (1887) figures a species of *Romingeria* which he identifies with the type. It is here considered as distinct. Two other very clearly defined forms are also added in the present paper,—*R. Jacksoni*, sp. nov., and *R. minor*, sp. nov.

Observations on Romingeria umbellifera.

PLATES I–V.

The specific characters of this type have been pretty fully and accurately stated in the description by Billings and Rominger, but as yet the illustrations published simply give one or two umbels without much suggestion as to the appearance of a large colony and without any details of internal structure.

The number of buds given off by the parent corallite at each period of proliferation is stated by Nicholson and Rominger to be from five to twelve, and one would be led to believe that twelve was the maximum attained by few, while the common number was somewhere between five and twelve.

hundred and thirty-nine, illustrating about a thousand different specimens. One hundred and seventy species are given names and marked as new species. They are without description of any sort. Seven new generic terms are proposed without definition. They are supposed to be corals, though some of them certainly are not (*e. g.*, *Nicholsonia=Hederella*, a Bryozoan), and all of them are probably synonyms of well-known genera (*e. g.*, *Antholites* and *Procteria=Pleurodictyum*).

In a careful count of one hundred discrete whorls, the writer has found that 41 per cent contain twelve buds, 28 per cent contain eleven, 16 per cent ten, 6 per cent nine, 5 per cent eight, and 4 per cent seven buds. In no instance has any number greater than twelve or less than seven been observed in separate umbels. The very unusual condition represented in the specimen, figures 8, 9, Plate I, shows two verticels crowded together so as to unite, and eleven corallites are suppressed in consequence. Of the fifteen remaining corallites, two (a, b,) are the parents, while six pertain to one umbel and seven to the other.

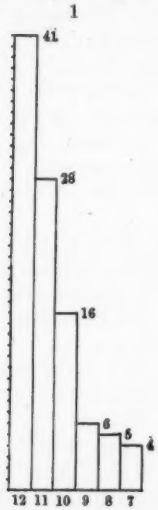


FIGURE 1.—Frequency polygon of *Romingeria umbellifera;* showing the number of buds in a hundred umbels; the abscissa shows the variation in the number of buds per umbel (seven to twelve), and the ordinate the number of individuals representing each. 41 per cent of the umbels have twelve buds, 28 per cent eleven, 16 per cent ten, 6 per cent nine, 5 per cent eight, and 4 per cent seven.

The frequency polygon is shown in text, figure 1. This indicates that what Billings meant by "sometimes ten or twelve" buds really means that 85 per cent of all the umbels have from ten to twelve buds springing from the parent corallite, and that twelve is the most common and therefore the characteristic number. There is a rapid falling off in the numbers below ten, and specimens with less than that must be considered as abnormal or pathologic.

The length of the internodes or the distance between the whorls measured along the corallites varies from 8 to 23^{mm}. Since the budding period is simultaneous for the whole corallum, and takes place on the same horizontal plane, it is evident that the internodes measured along one of the older parent corallites are shorter than along one of its daughter corallites, which rise obliquely from their origin to the next budding zone.

The corallites measure from 2 to 2·25^{mm} in diameter throughout most of their length. Just before starting to bud the tube enlarges to a diameter of 2·50 to 3^{mm}, and within the whorl of buds the parent corallite abruptly contracts to about 1·5^{mm} in diameter. The buds all spring from the beveled periphery of the parent corallite, with which they communicate by means of a large initial pore, figures 2, 3, Plate I. Both buds and

parent corallites develop tabulæ, usually convex, and most numerous within the region of the verticel. In other portions of the corallum they seem to be quite infrequent. Immediately above the row of initial pores there is a tabula in the parent corallite, sometimes showing a number of septal ridges which may correspond to the number of buds and are sometimes continued upward for a short distance as rows of septal spines, figures 3, 4, Plate I. No evidence of septa has been observed in any other portions of the corallites in the present collection. The buds before separating usually communicate with each other by one or two mural pores, as shown in figure 6, Plate I, but in no instance except in the initial pore previously mentioned has a bud within the umbel been seen to bear pores leading into the parent corallite. Also, whenever the corallites of the same or different verticels come in contact away from the whorls, the walls may be perforated by a pore, figure 7, Plate I.

The examination of a large mass of this coral, measuring nine inches or more in diameter (230^{mm}), shows its almost geometrical regularity in a striking degree. It is seen to be composed of a number of distinct superimposed horizontal zones or stories, separated by a distance of from 15 to 20^{mm}. The division planes consist of closely arranged rosettes formed by the whorls of buds given off at regular intervals in the upward growth of the corallum. Between the division planes or from the floor to the ceiling of each story are to be seen the simple columns of the individual corallites with their Corinthian-like capitals, which are to develop into a verticel of daughter corallites at the division plane above, Plate IV.

In a large corallum, each umbel of thirteen corallites (one parent and twelve buds) generally occupies a space of about 170 square millimeters. The size of this area was determined by enumerating the umbels occurring in several areas measuring 50 x 50^{mm}. The average showed fifteen umbels for this space, containing in the aggregate one hundred and ninety-five corallites.

One specimen measuring 100 x 200^{mm} on the horizontal surface has approximately 1500 corallites on each zone. Three zones are complete for the same area and together contain about 4500 corallites. Now if each of the 1500 corallites of the bottom zone gave origin to twelve buds the next zone would contain 19,500 corallites, and the same process would demand 253,500 corallites for the third zone. This shows a suppression of 243,000 corallites on two zones.

The suppression of corallites seems to be due principally to two causes: (*a*) The crowding of the umbels together in the

same plane and thus aborting many of the buds, which only grow to be a few millimeters in length or are entirely suppressed; and (*b*) the inability of many of the corallites to reach the next zone of budding before all the available space is taken up by verticels from other rapid growing and more favored corallites. Whenever the growth and budding are not seriously restricted as to space, it is found that from ten to twelve buds are almost invariably given off.

Altogether, the probabilities against the successful attainment of maturity with the growth of a single cycle of buds are seldom equaled among corals. In ordinary proliferation in a compound coral, a bud is developed when by a divergence of the corallites through growth a space is made to receive it, but in *Romingeria* the buds are thrown off without any reference to their future possibilities. If the pores of *Favosites* are considered as potential buds, then the amount of suppression in that genus is infinitely greater than in *Romingeria*. It should be noted, however, that in *Favosites* whenever a corallite once appeared it usually continued to grow until the death of the whole colony.

A diagram of two successive periods of proliferation for a single corallite of *R. umbellifera* is shown in Plate V, figure 1. The third zone of buds would number 2,197 corallites, the fourth 28,561, and so on, according to the permutation of the number 13.

Corallites subjected to pressure in the matrix often exhibit a tendency to split into longitudinal plates corresponding to the twelve mesenteries or primary septal divisions, figure 5, Plate I. The twelvefold nature of the walls may be developed in this way without any evidence of septa being preserved.

Romingeria commutata, sp. nov.

PLATE V, FIGURES 4, 5.

Romingeria umbellifera Davis, Kentucky Fossil Corals, pl. 76, fig. 1, 1887.

The specimens identified by Davis with the type of the genus have already been referred to as probably distinct. The growth of the corallum is lax and the budding of the corallites is irregular, not producing the storied appearance typical of *R. umbellifera*. No regularly developed 10–12 rowed umbels are present in the Kentucky specimens, which seem to give off bundles of buds rather than to form perfect rosettes. There is also a much stronger development of the 8–10 rows of trabeculæ, which are not confined wholly to the budding region, but may extend for considerable distances along the corallites and also appear at the accidental points of contact of two corallites where adventitious mural pores are

usually found, Plate V, figures 4, 5. The corallites are a little larger than in *R. umbellifera* from Leroy, New York, and the length of the internodes is often much greater, sometimes measuring 30^{mm} or more.

Formation and locality.—The type specimen is in the collections of the Museum of Comparative Zoology, Catalogue Number 8849, Kentucky Fossil Corals, Plate 76, figure 1, and is from the Corniferous limestone (Devonian) at the Falls of the Ohio, Louisville, Kentucky.

Romingeria Jacksoni, sp. nov.

PLATE V, FIGURES 2, 10-15.

Corallum consisting of slender, cylindrical, discrete corallites, measuring from ·7 to ·8^{mm} in diameter. At intervals of from 5 to 10^{mm} a whorl of seven buds is given off from each corallite. The buds are closely appressed to the parent for a distance of 1 or 2^{mm} and then turn outward often nearly at right angles for 2 or 4^{mm}, thence extending upward to the next budding zone. The walls of the parent corallite are expanded just before the buds appear, and abruptly contract within the verticel to a little less than their normal diameter. On the exterior the corallites are marked by fine concentric striæ. Tabulæ infrequent, most common in the region of the umbels. Septa or septal spines not observed. A large apical initial pore connects each daughter corallite with the parent, and adjacent corallites often show communicating pores, as in *R. umbellifera*.

Occasionally the corallites become agglomerated into a mass resembling a *Favosites*, though around the periphery the branches are discrete and give off the usual umbels of seven buds each. A section of the closely grouped corallites is represented in figure 10, Plate V, showing their prismatic form.

This very distinct and normal species of *Romingeria* can be readily recognized from *R. umbellifera* by the smaller diameter of the corallites, the relative greater length of the internodes, and especially by the number of buds in each verticel. In *R. umbellifera*, out of a hundred umbels only four contained seven buds, while 85 per cent had from ten to twelve, with twelve as the characteristic number. The present collections contain eighteen umbels of *R. Jacksoni*, and each one of these is composed of seven buds besides the parent corallite. From *R. minor*, this species is distinguished by its larger size and by the number of buds in a single verticel, which in that form number five.

The specific name is given in honor of Professor R. T. Jackson of Harvard University.

Formation and locality.—In the cherty layers of the Corniferous limestone (Devonian), near Leroy, Genesee County, New York.

Romingeria minor, sp. nov.

PLATE V, FIGURES 3, 6-9.

Besides the species already noted, there is another form in the present collection, which, though minute, seems to agree in all essential external generic features with the genotype. Only a few umbels of this species have been observed, but they are so constant in their characters and so distinct from the other species, that there is little hesitancy in describing them as new.

The corallites are cylindrical, measuring but ·3 to ·4^{mm} in diameter. The umbels contain five buds each. The buds are contiguous to the parent for a distance of ·5^{mm}, and then turn out abruptly at right angles. The specimens are mostly filled with silica, and evidences of tabulæ and trabeculæ are obscured.

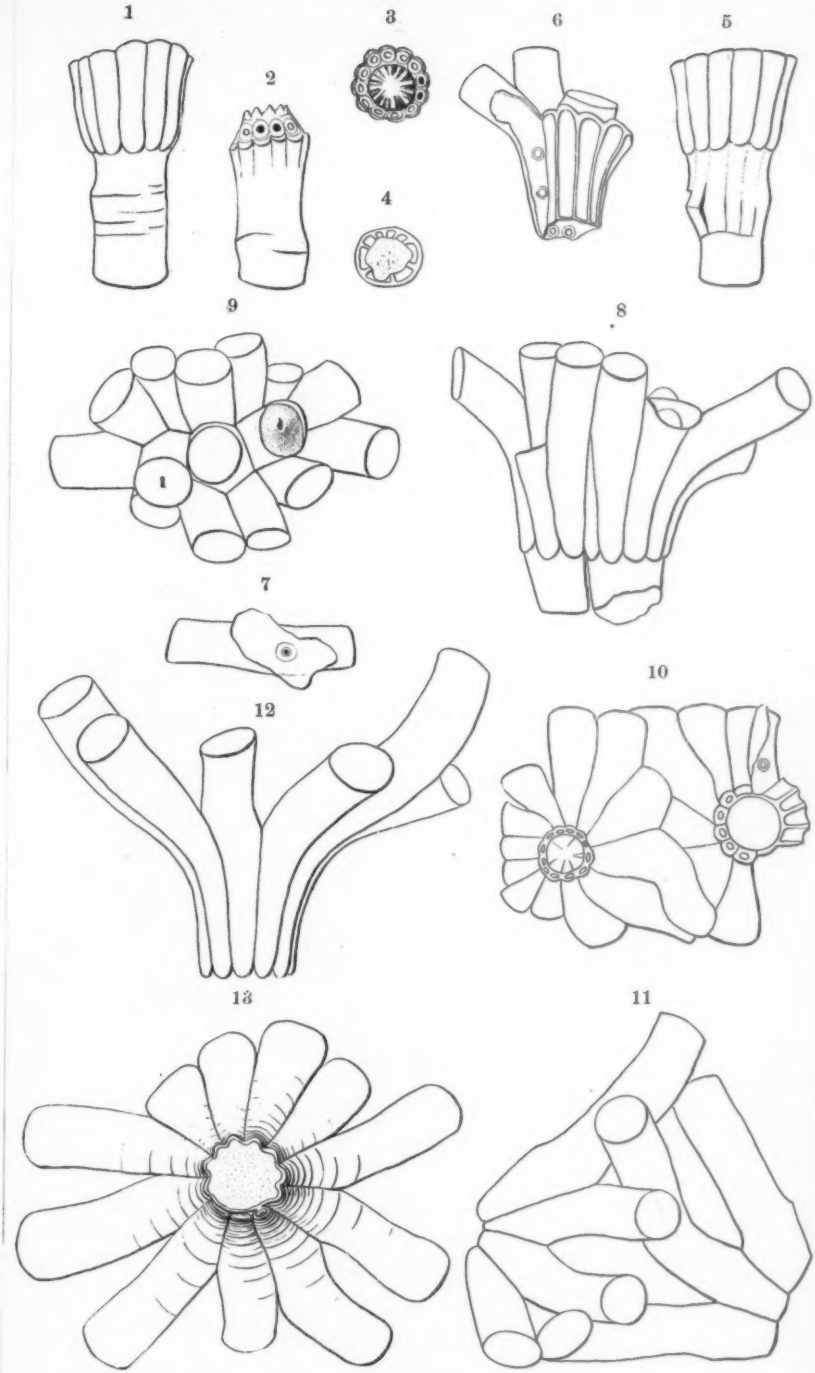
The diminutive size and the small number of buds in each umbel distinguish this species from the known members of the genus *Romingeria*.

Formation and locality.—In the Corniferous limestone (Devonian), near Leroy, New York.

Any discussion of the affinities of *Romingeria* with other genera of paleozoic tabulate corals must include the consideration of a number of genera, some of whose taxonomic positions are almost equally uncertain. On the one hand we are led to compare it with *Aulopora* and related forms, and on the other it appears that we are dealing with a type which in many ways is connected with *Favosites*. At the same time, certain genera often classed with the Bryozoa, as *Clonopora* and *Vermipora*, have close resemblances with it in some essential features, and should be treated in the same connection.

The main purpose of the present article is to make some contribution to the knowledge of the structure and habit of what are believed to be characteristic species of the genus *Romingeria*, and not to enter into a critical comparison with other genera. Some few remarks can not well be avoided, however, and the writer would again cite *Aulopora* as expressing a very simple type from which by progressive modifications a considerable number of more highly developed genera could be easily derived.

In a study of the ontogeny of *Pleurodictyum*, it was shown by the writer,[6] and also by Girty in *Favosites*,[7] that the initial corallite soon gave origin to a single bud which was connected with the parent by a large initial pore, and in this condition it was homologous with a young colony of *Aulopora* consisting of



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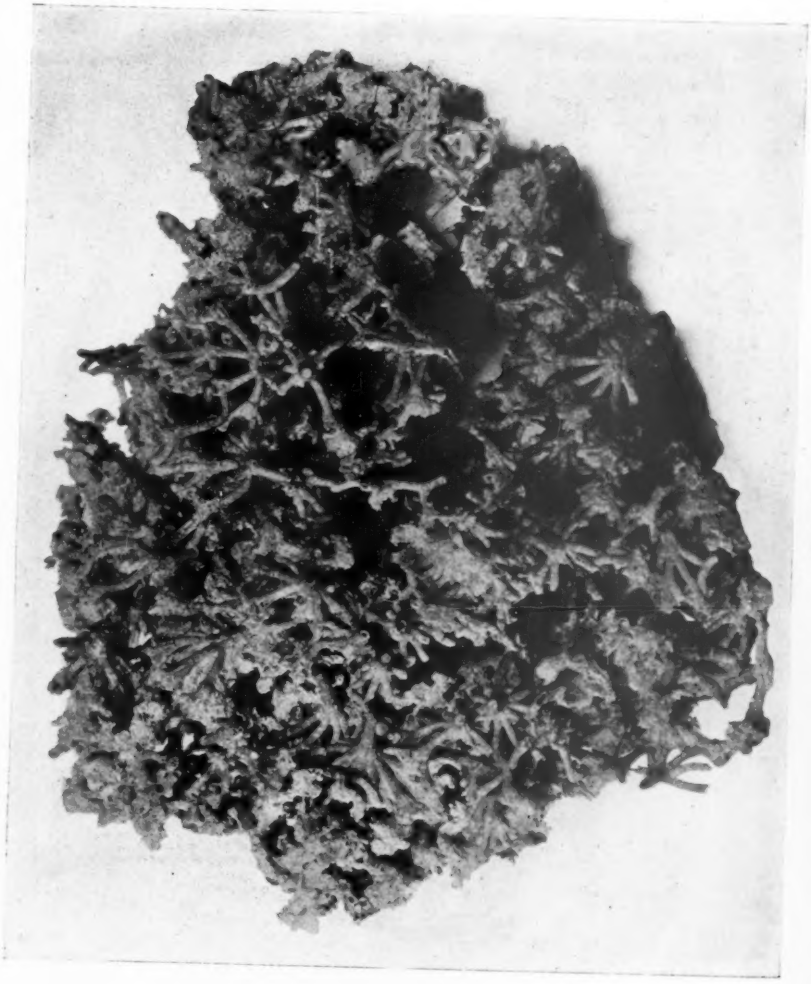

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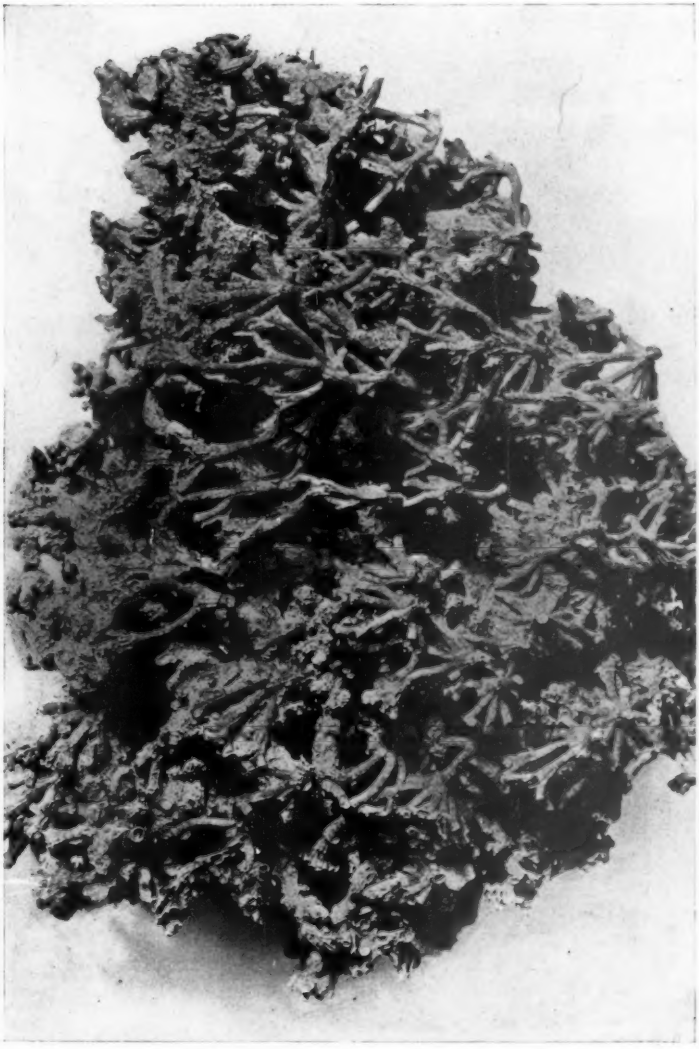

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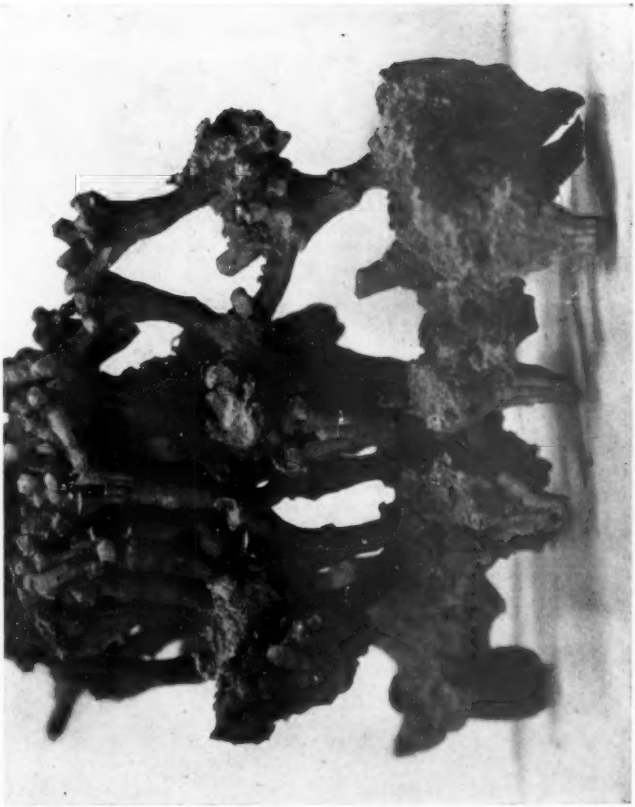

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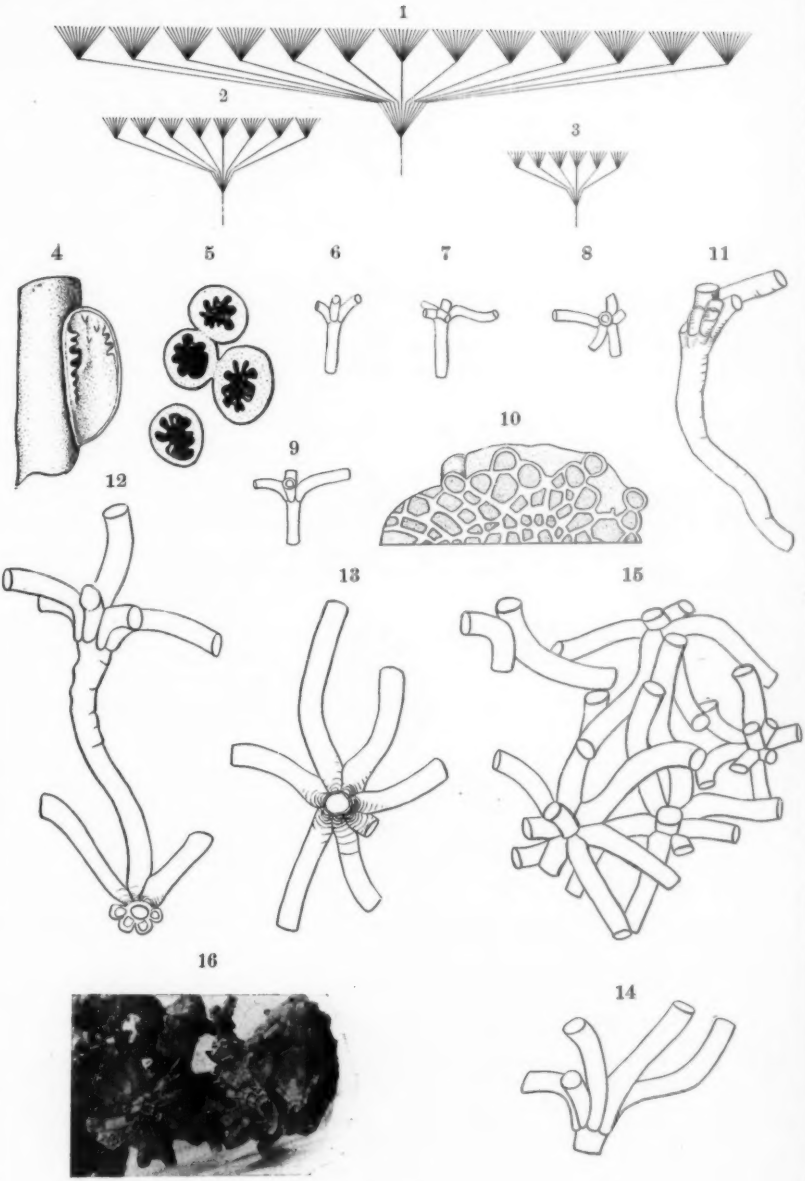

ROMINGERIA.

but two corallites. In *Pleurodictyum lenticulare* as in *Aulopora* no tabulæ are present, and the only structures within the tubes are rows of trabeculæ. It was also shown[5, 6] that the pores in the Favositidæ may be likened to aborted buds which attained no further development than the formation of a pore. The corallites in *Aulopora* generally give off one or two buds and then soon reach their limit of growth, while in *Romingeria* the corallites may grow to indefinite lengths and repeatedly send off whorls of buds.

It is well known that many species of *Favosites* develop faint septal longitudinal ridges or rows of spines. Typically these number twelve, thus agreeing with the characteristic number of buds and septa in *R. umbellifera*. The correspondence in the number of septa and mesenteries indicates that from each interseptal space buds may arise, so that *Favosites* has twelve proliferation potentialities at each complete cycle of budding.

Girty[7] has fully discussed these features in *Favosites*, and has shown that what should be considered as the archetypal form consists of an initial corallite with six primary radially arranged buds. Six interstitial cells constitute the next generation, and complete the cycle of twelve radii of gemmation.

These points of similarity in the budding habit of *Favosites* and *Romingeria*, together with the identity of most of their internal structures, clearly indicate their genetic affinities and point to their common origin.

Paleontological Laboratory, Yale University Museum, June 6, 1903.

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EXPLANATION OF PLATES.

PLATE I.

Romingeria umbellifera Billings, sp.

FIGURE 1.—Side view of portion of a normal corallite, with a circle of twelve buds at the summit. ×4.

FIGURE 2.—Side view of a corallite, with the buds removed; showing the large initial pores connecting the parent with the daughter corallites, and the abrupt constriction of the parent at the budding zone. The serrations of the summit are produced by the proximal ends of the septal ridges, and correspond in number with the buds. ×4.

FIGURE 3.—Top view of the preceding; showing the twelve initial pores connecting the buds with the parent corallite, and the twelve septal lines extending over the tabula of the parent corallite. ×4.

FIGURE 4.—A section of a corallite just above the budding zone; showing eight distinct septal spines. The center is filled with silica and the full extent of the septa obliterated. ×4.

FIGURE 5.—A specimen similar to figure 1, in which, from compression, the walls of the parent corallite have been split into vertical plates, corresponding to the septal divisions. ×4.

FIGURE 6.—Side view of an umbel from which all but two of the buds have been stripped, leaving their inner walls attached to the central or parent corallite. Two pores are shown on the left side of the figure, communicating between adjacent buds, and two of the initial pores are represented at the base. ×4.

FIGURE 7.—Showing point of contact of two corallites and the formation of a mural pore. ×4.

FIGURE 8.—Side view of two closely appressed umbels, causing a suppression of some of the buds. ×4.

FIGURE 9.—Top view of the preceding; showing fifteen corallites. *a* and *b* are the two parent corallites. Eleven buds have been suppressed. ×4.

FIGURE 10.—Basal view of two adjacent normal umbels of twelve buds each, in close contact, so that there are no interstices between the corallites. ×4.

FIGURE 11.—Showing the loose interlocking of the corallites from two adjacent umbels. ×4.

FIGURE 12.—Side view of an umbel containing eleven buds. ×4.

FIGURE 13.—Basal view of the same. ×4.

Corniferous limestone, near Leroy, New York.
Collection, Yale University Museum.

PLATE II.

Romingeria umbellifera Billings, sp.

FIGURE 1.—Basal view of a colony; showing the characteristic appearance of normal growth. Two-thirds natural size.

Corniferous limestone, near Leroy, New York.
Collection, Yale University Museum.

PLATE III.

Romingeria umbellifera Billings, sp.

FIGURE 1.—An oblique basal view of the specimen on the preceding plate; showing more distinctly the umbellate habit of growth. Above three-fourths natural size.

Corniferous limestone, near Leroy, New York.
Collection, Yale University Museum.

PLATE IV.

Romingeria umbellifera Billings, sp.

FIGURE 1.—Side view of a portion of a colony; showing the storied effect, with supporting columns, produced by the regular proliferation periods in this species. × ⅔.

PLATE V.

FIGURE 1.—Proliferation diagram of *Romingeria umbellifera* Billings, sp.; showing two generations of normal budding. The parent corallite is in the center.

FIGURE 2.—Proliferation diagram of *Romingeria Jacksoni* Beecher.

FIGURE 3.—Proliferation diagram of *Romingeria minor* Beecher.

Romingeria commutata Beecher.

FIGURE 4.—A portion of two branches in contact, with the walls of one broken away; showing the connecting mural pore and the rows of spinules. × 4.

Taken from specimen No. 8849, Collection of Museum of Comparative Zoology.

Type of figure 1, Plate 76, Kentucky Fossil Corals, W. J. Davis.

Corniferous limestone, Falls of the Ohio.

FIGURE 5.—The broken ends of four corallites from the same specimen; showing the strong lines of trabeculæ on the interior. × 4.

Romingeria minor Beecher.

FIGURE 6.—Side view of an umbel of this species. × 4.

FIGURE 7.—Side view of an umbel; showing the buds extending out at right angles to the parent corallite. Type. × 4.

FIGURE 8.—Top view of the preceding; showing the normal number of five buds in the verticel. × 4.

FIGURE 9.—Side view of an umbel similar to the preceding. × 4.

Corniferous limestone, near Leroy, New York.

Collection, Yale University Museum.

Romingeria Jacksoni Beecher.

FIGURE 10.—A longitudinal section of a corallum in which the corallites are prismatic, except on the exterior. The peripheral corallites turn outward on some parts of the specimen (not shown) and develop normal umbels. × 4.

FIGURE 11.—Side view of a corallite, with a broken circlet of buds at the top. One of the buds shows the initial pore, and the adjacent bud preserves a portion of a tabula. × 4.

FIGURE 12.—Two umbels taken from the specimen figure 14; showing characteristics of this species. × 4.

FIGURE 13.—Base of an umbel; showing the normal number of seven buds. × 4.

FIGURE 14.—Side view of the preceding. × 4.

FIGURE 15.—Top view of a portion of a colony; showing the general habit of growth. Type. × 4.

Corniferous limestone, near Leroy, New York.

Collection, Yale University Museum.

Romingeria umbellifera Billings.

FIGURE 16.—Basal view of a portion of the specimen shown on Plate IV; showing the disposition of the umbels. Natural size.

Corniferous limestone, near Leroy, New York.

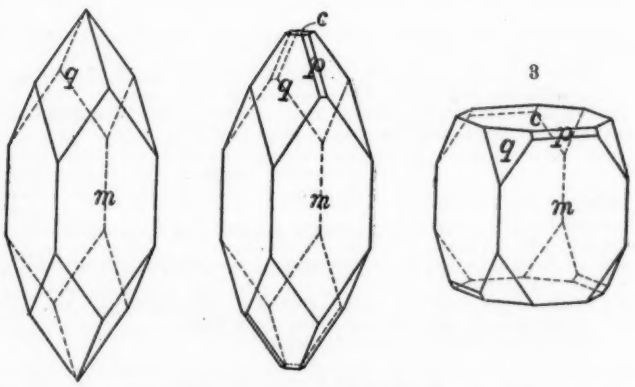
Collection, Yale University Museum.

ART. II. — *A Comparative Study of Some Isomorphous Triple Thiocyanates;* by J. C. BLAKE.

FOUR triple thiocyanates, recently prepared by Wells and others,* have been studied crystallographically. These salts have compositions represented by the following formulas:

$Cs_3Ag_3Ba(SCN)_9$,
$Cs_3Cu_2Ba(SCN)_7$,
$Cs_3Ag_2Sr(SCN)_7$,
$Cs_3Cu_2Sr(SCN)_7$.

1 2 3



The crystals are well suited for optical investigation, and are especially interesting because the sphenoidal group of the tetrahedral system, to which they belong, has few representatives, either natural or artificial, and because the salts are isomorphous and hence offer a new field for the comparative study of the physical and chemical properties involved. Unfortunately the number of salts belonging to the series which have been prepared is as yet too small to throw much light on the relative variations which change of composition induces, or to lend much weight to the conclusions reached.

The following forms have been observed:

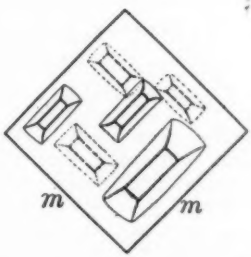
c (001)	*m* (110)	*q* (201)
a (100)	*p* (111)	

The general habit of the crystals is indicated by the illustrations, figures 2 and 3 showing the sphenoid *p* (111). The

* Am. Chem. Jour., xxviii, 245.

sphenoidal character of the crystals was more fully established for all of the salts of the series by the binary character of the etchings on basal cleavage surfaces. The basal cleavage is a pronounced feature of all the salts, hence basal sections for etching and for optical examination could readily be obtained. The etched figures, in no case very distinct, were best obtained by using dilute ammonium hydroxide as the solvent. The characters obtained are sketched in figure 4, and exhibit plainly the binary symmetry of the vertical axis. Moreover, on opposite faces of the same basal section the figures were orientated at right angles to one another, as indicated by full and dotted lines in the figure. In this way the sphenoidal character of the silver-barium salt was established, although the sphenoidal

4



faces, p (111) were not present on any of the crystals observed. Indeed, the sphenoidal character of this salt, the first one of the series which was prepared and studied, was unsuspected until after the other salts had been examined.

The crystals studied were from one millimeter to one centimeter in thickness, with the proportionate lengths represented in the figures, and exhibited some tendency to arrange themselves in parallel groups. One large individual of the silver-strontium salt in particular seemed to be made up of a collection of smaller ones in parallel position, the separate pyramidal faces, q(201), being readily discernible. The crystals are clear and colorless when not tinged with impurities, and, with the exception of the silver-strontium salt, give good reflections with the goniometer.

Basal sections of all of the salts, when examined with the polariscope, exhibit the normal interference figure of uniaxial crystals, and, when tested with the mica plate, the salts were proved to be optically negative. The well developed pyramidal faces, q, 201, and q'', $\bar{2}01$, of the several salts served as prisms whereby the indices of refraction were determined for sodium light.

$Cs_3Ag_2Ba(SCN)_7$.

The crystals of this salt have the habit shown in figure 1, consisting of the prism, m (110), and the pyramid of opposite order, q (201), although the basal plane, c (001), only slightly developed, is sometimes present. Its external form gives no indication of its sphenoidal character. The following angles were measured, the asterisk marking the fundamental measurement:

	Measured.	Calculated.
$q \wedge q''$, $201 \wedge \bar{2}01$	122° 14′*	
$q \wedge q'$, $201 \wedge 021$	76° 30′	76° 30′
$m \wedge q$, $110 \wedge 201$	51° 45′	51° 45′

Vertical axis $c = 0{\cdot}9063$.
Indices of refraction for sodium light:

$\omega = 1{\cdot}7761$; $\epsilon = 1{\cdot}6788$. Difference $= 0{\cdot}0973$.

$Cs_3Cu_2Ba(SCN)_7$.

The crystals of this salt sometimes have the same habit as that of the silver-barium compound, figure 1, but usually they are modified by the sphenoidal faces, p (111), and the base, c (001), as shown in figure 2. In one crop of crystals more than twenty individuals were examined, and no variation was observed in the distribution of the p faces, truncating the alternate edges of the pyramid of the second order, q (201), thus clearly establishing the sphenoidal character of the crystallization. Another lot of crystals presented a very different, almost cubical appearance, owing to the large development of the basal plane, c, figure 3, with the pyramid of the second order q, and the sphenoid, p, only slightly developed. Here, again, there was no variation in the distribution of the faces of the sphenoid, p, replacing the alternate edges between c and m. On one crystal a single but well-developed face of the prism of the second order, a (100), was observed, this being the only observation of this form on any of the salts of the series. The following angles were measured:

	Measured.	Calculated.
$q \wedge q''$, $201 \wedge \bar{2}01$	122° 52′*	
$q \wedge q'$, $201 \wedge 021$	76° 44′	76° 47′
$m \wedge q$, $110 \wedge 201$	51° 38′	51° 37′
$c \wedge p$, $001 \wedge 111$	52° 23′	52° 24′

Vertical axis $c = 0{\cdot}9183$.
Indices of refraction for sodium light:

$\omega = 1{\cdot}8013$; $\epsilon = 1{\cdot}6882$. Difference $= 0{\cdot}1131$.

$Cs_2Ag_2Sr(SCN)_7$.

The habit of this salt is the same as that of the silver-barium compound, except that the sphenoidal faces, p (111), were observed on two crystals out of twenty, as in figure 2. The reflections were only fair at the best, although fifty or sixty individual crystals, obtained from four or five different crops, were examined. Hence the optical data obtained are valueless for comparison with those of the other salts studied, although they are sufficiently characteristic to bring this salt clearly within the series. The following angles were measured:

	Measured.	Calculated.
$q \wedge q''$, $201 \wedge \bar{2}01$	122° 46′*	
$q \wedge q'$, $201 \wedge 021$	76° 35′	76° 44½′
$m \wedge q$, $110 \wedge 201$	51° 42′	51° 38′
$c \wedge p$, $001 \wedge 111$	52° 29′	52° 21′

Vertical axis $c = 0{\cdot}9165$.

$Cs_2Cu_2Sr(SCN)_7$.

The habit of these crystals is much like that of the copper-barium salt, but the sphenoidal faces, p (111), and the base, c (001), are generally more largely developed than in figure 2, the p faces being often as large as the faces of the pyramid of the second order, q (201). Indeed, the sphenoidal faces are more pronounced and more generally present on this than on any other salt of the series. The following angles were measured:

	Measured.	Calculated.
$q \wedge q''$, $201 \wedge \bar{2}01$	122° 44′*	
$q \wedge q'$, $201 \wedge 021$	76° 41′	76° 43½′
$m \wedge q$, $110 \wedge 201$	51° 39′	51° 38′
$c \wedge p$, $001 \wedge 111$	52° 18′	52° 20′

Vertical axis $c = 0{\cdot}9158$.

Indices of refraction for sodium light:

$\omega = 1{\cdot}8535$; $\epsilon = 1{\cdot}6982$. Difference $= 0{\cdot}1553$.

Comparative Study.

It will be observed that the indices of refraction are high, and that the birefringence is likewise high. Further, the relative values of the indices of refraction for the ordinary and extraordinary rays confirm the evidence obtained by use of the mica plate that the material is optically negative. The regularity of the physical and chemical variations is made evident in the following table of collected results:

Salt.	Molec. weight.	Development of p (111).	c	ω	ϵ	Birefringence.
Cs–Ag–Ba	1042·5	Absent	0·9063	1·7761	1·6788	0·0973
Cs–Cu–Ba	998·2	Slight	0·9183	1·8013	1·6882	0·1131
Cs–Ag–Sr	993·3	Slight	0·9165*	-----	-----	--- -
Cs–Cu–Sr	949·0	Large	0·9158	1·8535	1·6982	0·1553

The salts have been arranged in order of decreasing molecular weight. It will be noticed that as the heavier metals are replaced by lighter ones, both indices of refraction, as well as the birefringence, grow successively greater, although the opposite behavior might have been expected. The development of the sphenoidal form, p (111), shows a similar regularity; whereas the lengths of the vertical axis show the inverse relation, except for that of the silver-barium salt. Hence one might conclude that: (1) Similarity of the atomic weights of the basic elements, as in the case of the cæsium-silver-barium compound, tend to decrease both the indices of refraction and the birefringence, and also to suppress the sphenoidal form; (2) Neither the chemical composition nor the optical properties bear a simple relation to the length of the vertical axis.

Attempts to obtain other members of the series for further comparison, as by substituting rubidium for cæsium, have so far been unsuccessful.

The kind advice and supervision of Prof. S. L. Penfield is gratefully acknowledged; also the kindness of Prof. H. L. Wells and his assistants in supplying the crystals examined.

Mineralogical Laboratory of Sheffield Scientific School,
Yale University.

*Repeated attempts to obtain the indices of refraction were unsuccessful, apparently on account of the great solubility of the material and the consequent difficulty of separating the crystals from the concentrated mother liquor in good condition for crystallographic study. The crystal faces were always somewhat uneven, and the reflections consequently blurred; hence the length of the vertical axis, also, is less reliable than the values given for the other salts.

ART. III.—*Studies in the Cyperaceæ;* by THEO. HOLM. XIX. The genus *Carex* in Colorado. (With figures in the text, drawn by the author.)

HAVING given an account of some critical species of *Carex* from this State in previously published papers, we now present a more general sketch of the genus, as represented in the Rocky Mountains of Colorado, including a synopsis of the species, some notes on those which are new or little known together with their geographical distribution. We have not, however, succeeded in getting together all the vast material that exists from this State, collected by various explorers during nearly half a century, but we have brought together as much as possible, including our own collections made during two summer excursions in these mountains, which may, perhaps, give an adequate idea of the representation of the genus in Colorado.

In cases where species have been described only preliminarily and rather incompletely we have inserted a diagnosis; besides that certain corrections have been made in regard to the structure of the flower, rhizome, etc.

The flora of Colorado is comparatively little known, and it is really surprising to see from the map how many and wide areas are still unexplored. Nevertheless many and large collections have been gathered from these mountains, and the results published in the shape of "lists" in various publications. We have thought, therefore, that any contribution to the knowledge of this most interesting flora might be of some use for future studies; besides that the notes upon the geographical distribution might be of interest from this point of view, demonstrating the existence of arctic and even circumpolar species on the higher peaks of these mountains. And the genus *Carex*, when compared with the other large genera which we have studied in Colorado, gives really an excellent idea of the character of the vegetation in these regions with representatives of northern and southern types, boreal and alpine, endemic and such as are common to the mountains of both worlds. We should not, however, have been in the position to offer such data in regard to the distribution or in regard to the habit of many species, if it were not for the exquisite collections presented to the writer through the kindness of Mr. James M. Macoun of Ottawa. No species can be properly understood unless studied from several stations, and as remote as possible. The Canadian *Carices* exhibit many characteristics, which are less pronounced in their southern representatives or, at least, their homologues, a fact

that becomes only too evident when we remember the predominance of the genus in northern and colder regions. The study of *Carex atrata* L., for instance, offers an excellent example of the danger in considering specimens from a few stations: the species in Colorado embraces two types and the Canadian three, of which only the one, the typical *atrata*, is common to both regions; of these, *C. ovata* Rudge seems restricted to the northeastern corner of this continent. Nevertheless all four types have at various times been considered identical. Several instances of a similar nature might easily be enumerated, and it is, altogether, a most difficult task to segregate or combine species in a genus as large as *Carex*. The proposition of a few new species is the result of a careful study of allies and homologues, yet the species themselves are only of some interest as far as concerns their characteristics modified, but nevertheless referable to some allied type or types with which they may have developed.

It seems altogether as if the Rocky Mountains have been the center of development of a number of types, many of which are endemic, while others participated in the migration along with the arctic plants towards the North where they became distributed; some of these have even become circumpolar.* But besides these two elements of vegetation, that may be considered as having originated in the Rocky Mountains themselves, a third one and perhaps the most interesting is composed of arctic plants which having been forced southward during the glacial epoch, remained there, making their homes on the lofty mountain summits, where they are yet in existence. These northern and southern types are especially alpine or subalpine and may, at least to some extent, throw some light upon the great problem of the origin and distribution of the arctic flora.

A. *Synopsis of the Species.*

Vigneæ

Brachystachyæ Holm.

Carex canescens L. 39°–41° (Hall and Harbour, C. C. Parry); Trapper's Lake (C. S. Crandall); common in bogs near Bob Creek, La Plata Mts., alt. 10,500 ft. (Baker, Earle and Tracy); Marshall Pass, alt. 10,000 ft. (C. F. Baker).

C. tenella Schk. 39°–41° (Hall and Harbour, C. C. Parry); Bob Creek, La Plata Mts., alt. 10,500 ft. (Baker, Earle and Tracy); moist, shaded places in Spruce-woods on mts. near Pagosa Peak, alt. 9000 ft. (C. F. Baker); in swamp, Graymont (C. S. Crandall); common in swamps on Mt. Elbert, alt. 10,000 ft. and along Quail Creek near Steven's Mine, alt. 10,500 ft. (the author).

*Compare: A. G. Nathorst: Polarforskningens Bidrag til Forntidens Växtgeografi (in Nordenskiölds Studier och Forskningar. Stockholm, 1883.) See also: Same author in Engler's bot. Jahrb., 1891, p. 218, etc.

Neurochlænæ Holm.

C. nardina Fr. Mt. Elbert, alt. 12,000 ft. (the author).

Argyranthæ Holm.

C. Deweyana Schw. 39°–41° (Hall and Harbour, C. C. Parry).

Astrostachyæ Holm.

C. gynocrates Wormskj. South Park (I. Wolfe).
C. stellulata Good. var. Wet Mountain Valley (T. S. Brandegee).

Acanthophoræ Holm.

C. occidentalis Bail. La Plata River, alt. 9,000 ft., and Mt. Hesperus, alt. 10,000 ft. (Baker, Earle and Tracy).
C. Hookeriana Dew. Hills about Trinidad (C. S. Crandall); dry meadows at Dix (Baker, Earle and Tracy); moist places, Los Pinos (C. F. Baker).
C. Hoodii Boott. Four mile Hill, Routt County (C. S. Crandall).

Xerochlænæ Holm.

C. marcida Boott. Moist meadow, College farm and river-flats at Ft. Collins (C. S. Crandall); Durango, alt. 6,500 ft. (Baker, Earle and Tracy); abundant in moist meadows near Pagosa spring (C. F. Baker).
C. Sartwellii Dew. 39°–41° (Hall and Harbour, C. C. Parry); South Park (T. C. Porter).
C. Douglasii Boott. 39°–41° (Hall and Harbour, C. C. Parry); near Long's Peak (J. M. Coulter); river-flats at Ft. Collins and in swamps on the plains near Ft. Collins (C. S. Crandall); La Plata River, alt. 9,000 ft. (Baker, Earle and Tracy); Gunnison, common in meadows (C. F. Baker); in the Spruce-zone, headwaters of Clear Creek, alt. 10,000 ft. (the author).

Phænocarpæ Holm.

C. teretiuscula Good. Hamor's Lake (Baker, Earle and Tracy).

Cephalostachyæ Holm.

C. fœtida All. Little Kate Mine, alt. 11,500 ft. (Baker, Earle and Tracy).
C. stenophylla Wahl. 39°–41° (Hall and Harbour, C. C. Parry).

Athrostachyæ Holm.

C. athrostachya Olney. Mt. Massive, alt. 11,000 ft. (the author).
C. festiva Dew. 39°–41° (Hall and Harbour, C. C. Parry); Ute Pass (T. C. Porter); White House Mt. and Mt. Lincoln, alt. 12,000 ft. (J. M. Coulter); Pike's Peak (W. M. Canby); La Plata River, alt. 9,000 ft. (Baker, Earle and Tracy); Gunnison (C. F. Baker); Georgetown and Silverplume (P. A. Rydberg); not uncommon in the Aspen- and Spruce-zones from Silverplume to Steven's Mine, alt. 9,500–10,300 ft., and on Gray's Peak, alt. 13,000 ft. (the author).

C. festiva Dew. var. *Haydeniana* (Olney) W. Boott. Cameron Pass (C. S. Crandall); Marshall Pass, Gunnison Watershed, alt. 10,000 ft. (C. F. Baker); common on hillsides, mts. at Pagosa Peak, alt. 12,000 ft. (C. F. Baker); Silverplume (P. A. Rydberg); Mt. Kelso, alt. 12,000 ft., Thompson's Canyon on Long's Peak, alt. 10,500 ft., Mt. Massive, alt. 12,000 ft., Mt. Elbert, abundant in damp places, alt. 11,500 ft. (the author).

C. festiva Dew. var. *pachystachya* Bail. Bob Creek (Baker, Earle and Tracy); banks of streams, mts. near Pagosa Peak, alt. 9,500 ft. (C. F. Baker).

C. festiva Dew. var. *stricta* Bail. Walton Creek flats, Routt County (C. S. Crandall); common in meadows and along brooks, Georgetown and Silverplume (P. A. Rydberg).

C. festiva Dew. var. *decumbens* Holm. Mts. near Pagosa Peak, alt. 12,000 ft. (C. F. Baker); abundant on grassy slopes of Mt. Kelso near Steven's Mine, alt. 12,000 ft. (the author).

C. petasata Dew. 39°–41° (Hall and Harbour, C. C. Parry); Cameron Pass, at timber line (C. S. Crandall); La Plata River, alt. 10,000 ft. (Baker, Earle and Tracy); James Peak, alt. 13,000 ft., Mt. Massive, alt. 12,000 ft. and Mt. Kelso, alt. 12,000 ft. (the author).

C. pratensis Drej. Stove Basin, Laramie Co. (G. E. Osterhout); Howe's Gulch (C. S. Crandall); not uncommon on dry, grassy slopes near Long's Peak, alt. 8,600 ft. (the author).

C. siccata Dew. 39°–41° (Hall and Harbour, C. C. Parry); River-bank, Ft. Collins (C. S. Crandall); La Plata River, alt. 10,000 ft. (Baker, Earle and Tracy); Mt. Massive, alt. 11,000 ft., Mt. Kelso, alt. 12,000 ft. and on Lamb's Ranch near Long's Peak, alt. 8,600 ft. (the author).

C. Liddonii Boott. Campton's Ranch (C. S. Crandall).

C. Bonplandii Kunth var. *minor* Olney. 39°–41° (Hall and Harbour, C. C. Parry); near the snowbanks, headwaters of Clear Creek, alt. 12,000 ft. (the author).

Pterocarpæ Holm.

C. straminiformis Bail. West Mancos Canyon, alt. 9,500 ft. (Baker, Earle and Tracy).

Sphærostachyæ Holm.

C. incurva Lightf. Alpine ridge near Middle Park (C. C. Parry); Gray's Peak (Patterson); Silverplume (P. A. Rydberg).

CARICES GENUINÆ

Melananthæ Drej.

C. alpina Sw. 39°–41° (Hall and Harbour, C. C. Parry); Headwaters of Beaver Creek, 50 miles south of Ft. Collins, alt. 10,000 ft. (C. S. Crandall); South Park (J. Wolfe); Upper La Plata River, alt. 10,000 ft. (Baker, Earle and Tracy); Idaho Springs (P. A. Rydberg); Georgetown (Patterson).

C. alpina Sw. var. *Stevenii* Holm. Not uncommon in the Aspen zone: Middle Park (Beardslee); Georgetown (P. A. Rydberg); Silverplume, alt. 9,500 ft.; swamps on Lamb's Ranch near Long's Peak, alt. 8,600 ft.; abundant in the Spruce zone: between Graymont and Steven's Mine, very seldom alpine: Gray's Peak, alt. 12,000 ft, associated with *Juncus triglumis* and *Carex misandra* (the author).

C. melanocephala Turcz. 39°–41° (Hall and Harbour, C. C. Parry); Upper La Plata, alt. 10,000 ft. (Baker, Earle and Tracy); Chamber's Lake (C. S. Crandall); Silverplume (P. A. Rydberg); mts. about Ouray (C. S. Crandall); very abundant in thickets of *Salix* on Mt. Elbert, alt. 11,500 ft.; on Mt. Kelso at 11,500 ft. and headwaters of Clear Creek, alt. 11,000 ft. (the author).

C. atrata L. 39°–41° (Hall and Harbour, C. C. Parry); Long's Peak, alt. 12,500 ft. and Gray's Peak, alt. 12,500 ft. (the author).

C. chalciolepis Holm. Little Kate Mine, La Plata Mts., alt. 11,000 ft. and Mt. Hesperus, alt. 11,500 ft. (Baker, Earle and Tracy); along brooks at Silverplume (P. A. Rydberg); Cameron Pass, timber line (C. S. Crandall); mts. near Pagosa Peak, on hillsides, alt. 12,000 ft. (C. F. Baker); James' Peak, alt. 13,000 ft., Mt. Massive, alt. 12,000 ft., Mt. Elbert, alt. 12,000 ft., Mt. Kelso, alt. 12,000 ft., Long's Peak, alt. 12,000 ft., Thompson's Canyon on Long's Peak, alt. 10,500 ft. and Gray's Peak, alt. 12,000 ft. (the author).

C. bella Bail. 39°–41° (Hall and Harbour, C. C. Parry); Mt. Hesperus, near Bob Creek and Upper La Plata, alt. 10,000 ft. (Baker, Earle and Tracy).

C. Parryana Dew. 39°–41° (Hall and Harbour, C. C. Parry); swamps at Twin Lakes, alt. 9,265 ft. (the author).

C. Buxbaumii Wahl. 39°–41° (Hall and Harbour, C. C. Parry).

Microrhynchæ Drej.

C. vulgaris Fr.; in moist ground, associated with *Platanthera* and *Pyrola* in the Aspen zone near Silverplume, alt. 9,500 ft. (the author).

C. rigida Good. near the snowbanks, headwaters of Clear Creek, alt. 11,500 ft. (the author).

C. scopulorum Holm. Marshall Pass, alt. 12,000 ft., abundant in wet places, covering extensive areas (C. F. Baker); mts. of Estes Park (G. E. Osterhout). Silverplume (P. A. Rydberg); abundant in swamps in the Spruce zone, Mt. Massive, alt. 11,000 ft., headwaters of Clear Creek, alt. 11,000 ft., common in swamps from Steven's Mine to Mt. Kelso and Gray's Peak, alt. 12,000 ft. (the author).

C. chimaphila Holm. Along brooks, associated with *Juncus biglumis, J. triglumis* and *J. castaneus* on Long's Peak, alt. 12,000 ft. (the author).

C. variabilis Bail. 39°–41° (Hall and Harbour, C. C. Parry); Twin Lakes (J. Wolfe); Leadville, Ute Pass (W. Trelease); wet places near Empire and along Clear Creek (Patterson); Cameron Pass (C. S. Crandall); Georgetown (P. A. Rydberg); swamps on Mt. Massive, alt. 11,000 ft., and Mt. Kelso (the author).

C. variabilis Bail. var. *sciaphila* Holm. Shaded places in the Spruce zone, Mt. Massive, alt. 11,000 ft. (the author).

C. acutina Bail. Silverplume and Georgetown (P. A. Rydberg); Graymont, in swamps on Lamb's Ranch, alt. 8,600 ft., and James' Peak, alt. 10,000 ft. (the author).

C. acutina Bail. var. *petrophila* Holm. On dry rocks near Graymont, alt. 9,500 ft. (the author).

C. Nebrascensis Dew. 39°–41° (Hall and Harbour, C. C. Parry); Oak Creek (T. S. Brandegee); Weston Pass and Twin Lakes (J. M. Coulter); Monument Park (T. C. Porter); swamp on the Plains near Ft. Collins and in ditch College Farm (C. S. Crandall).

C. rhomboidea Holm. Common in swamps on Lamb's Ranch near Long's Peak, alt. 8,600 ft., and Twin Lakes, alt. 9,265 ft. (the author).

Cenchrocarpæ Holm.

C. aurea Nutt. Mancos, alt. 7,000 ft. and West Mancos Canyon, alt. 9,000 ft. (Baker, Earle and Tracy); Los Pinos, in moist places, Piedra, along streamlets and near Gunnison (C. F. Baker); Mt. La Plata, alt. 11,000 ft. (J. M. Coulter); bank of Elk River, Routt County (C. S. Crandall); Clear Creek Canyon near Graymont, alt. 9,500 ft. (the author).

C. Torreyi Tuckm. On grassy slopes, in openings among *Pinus ponderosa* near Golden City (E. L. Greene).

Lejochlænæ Holm.

C. polytrichoides Muehl. 39°–41° (Hall and Harbour, C. C. Parry).

C. Geyerii Boott. 39°–41° (Hall and Harbour, C. C. Parry); Chamber's Lake (C. S. Crandall); Bob Creek, on dry ridges and meadows, alt. 10,500 ft. (Baker, Earle and Tracy).

Elynanthæ Holm.

C. filifolia Nutt. 39°–41° (Hall and Harbour, C. C. Parry); Ute Pass (T. C. Porter); Table Rock (G. F. Benninger); Silverplume (P. A. Rydberg).

C. elynoides Holm. On bare mountain tops near Pagosa Peak, alt. 12,000 ft. (C. F. Baker); Mt. Massive, alt. 12,000 ft., and Mt. Kelso, alt. 12,000 ft. (the author).

Lamprochlænæ Drej.

C. rupestris All. 39°–41° (Hall and Harbour, C. C. Parry); Gray's Peak (Patterson); Cumberland Mine, alt. 12,300 ft. (Baker, Earle and Tracy); very scarce on dry slopes of James' Peak, alt. 13,000 ft., Mt. Elbert, alt. 12,000 ft., Long's Peak, alt. 12,000 ft., and Gray's Peak, alt. 12,500 ft. (the author).

C. obtusata Liljebl. 39°–41° (Hall and Harbour, C. C. Parry); Georgetown (Patterson); South Park (J. Wolfe); Chicken Creek, alt. 9,500 ft. (Baker, Earle and Tracy); common in dry, sandy soil near Long's Peak, alt. 8,600 ft. (the author).

Athrochlænæ Holm.

C. nigricans C. A. Mey. 39°–41° (Hall and Harbour, C. C. Parry); Black Lake in Thompson's Canyon on Long's Peak, alt. 10,300 ft. and common along brooks, headwaters of Clear Creek, alt. 11,000 ft. (the author).

C. pyrenaica Wahl. 39°–41° (Hall and Harbour, C. C. Parry); mountains west of Cameron Pass (C. S. Crandall); mountains near Pagosa Peak, alt. 12,000 ft. (C. F. Baker); Long's Peak, alt. 12,000 ft., on dry rocks, and Gray's Peak, alt. 13,000 ft. (the author).

Stenocarpæ Holm.

C. misandra R. Br. Along brooks on Gray's Peak, alt. 12,000 ft. (Patterson and the author).

Sphæridiophoræ Drej.

C. scirpoidea Michx. 39°–41° (Hall and Harbour, C. C. Parry); South Park (T. C. Porter).

C. oreocharis Holm. Common near Golden City (E. L. Greene); on dry rocks in the Aspen zone at Lamb's Ranch near Long's Peak, alt. 8,600 ft. (the author).

C. Pennsylvanica Lam. Trail Creek and Riot Canyon (C. S. Crandall); Ute Pass (T. C. Porter); mountains near Central City, alt. 8,500 ft. (the author).

C. Rossii Boott. 39°–41° (Hall and Harbour, C. C. Parry); headwaters of Beaver Creek, 50 miles W. of Ft. Collins and Chamber's Lake (C. S. Crandall); common on moist mountain slopes, Silverplume (P. A. Rydberg and C. L. Shear); Little Kate Mine, alt. 11,500 ft. (Baker, Earle and Tracy); in the Spruce zone on mountains near Pagosa Peak, alt. 11,500 ft. (C. F. Baker); under Spruce on Mt. Massive, alt. 11,000 ft. and headwaters of Clear Creek, alt. 11,000 ft. (the author).

C. umbellata Schk. var. *brevirostris* Boott. Near Golden City (E. L. Greene).

Spirostachyæ Drej.

C. viridula Michx. Hamor's Lake (Baker, Earle and Tracy).

Trichocarpæ Holm.

C. lanuginosa Michx. South Park (W. M. Canby); Ute Pass (T. C. Porter); Canyon City (T. S. Brandegee); Campton's Ranch (C. S. Crandall); Durango, alt. 6,500 ft. (Baker, Earle and Tracy); Pagosa spring and wet places, Gunnison (C. F. Baker); along creeks in Estes Park (the author).

C. aristata R. Br. River-bank near Ft. Collins, alt. 5,000 ft. (C. S. Crandall).

Hymenochlænæ Drej.

C. capillaris L. 39°–41° (Hall and Harbour, C. C. Parry); Devil's Causeway (C. S. Crandall); West Mancos Canyon (Baker, Earle and Tracy); Bear Lake in Thompson's Canyon on Long's Peak, alt. 10,700 ft., in swamps at Twin Lakes, alt. 9,265 ft., and at a spring in the Aspen zone near Silverplume, alt. 10,000 ft. (the author).

C. Backii Boott. 39°–41° (Hall and Harbour, C. C. Parry).

C. longirostris Torr. var. *minor* Boott. 39°–41° (Hall and Harbour, C. C. Parry).

Echinostachyæ Drej.

C. microglochin Wahl. 39°–41° (Hall and Harbour).

Physocarpæ Drej.

C. Engelmannii Bail. Upper Clear Creek region, alt. 12,000 ft. (G. Engelmann); high mountains near Silverplume (P. A. Rydberg).

C. utriculata Boott var. *minor* Boott. 39°–41° (Hall and Harbour, C. C. Parry); Middle Park and Trapper's Lake (C. S. Crandall); Bob Creek, alt. 10,000 ft. (Baker, Earle and Tracy); mountains near Pagosa Peak, alt. 10,000 ft. and common in wet bottom, Gunnison (C. F. Baker).

C. pulla Good. Deep Creek Lake (C. S. Crandall).

C. monile Tuckm. Hamor's Lake, alt. 9,000 ft. (Baker, Earle and Tracy).

C. rostrata Stokes. Hamor's Lake, alt. 9,000 ft. (Baker, Earle and Tracy).

Rhynchophoræ Holm.

C. lupulina Muehl. Durango, alt. 6,500 ft. (Baker, Earle and Tracy).

B. *Notes on new or little known species from Colorado.*

Carex nardina Fr.

The plant which we collected upon Mt. Elbert shows a peculiar deviation from the type by being tristigmatic, besides that the utricle is very prominently slit on the outer or convex face. We have not, however, felt justified in regarding this as a distinct species, inasmuch as the number of stigmas is not a constant character within the genus *Carex*, even if the species in question be one of the *Vigneæ*. It is, also, to be pointed out that we were unable to detect any divergence whatsoever in the anatomical structure of the vegetative organs which we compared with those of typical individuals from Greenland, Norway, Alaska and British Columbia. Similar specimens with three stigmata were also observed in the copious material

presented to the writer through the kindness of Mr. James M. Macoun, which was collected "on mountain summits, alt. 7,400 ft., at the headwaters of Fraser River in British Columbia."

Carex occidentalis Bailey.

Rhizome short, creeping, forming dense mats, with persisting, dark-brown sheaths; leaves glaucous, shorter than the culm, narrow, but flat, scabrous along the margins; culms numerous, from 20 to 60^{cm} in height, slender, triangular, scabrous, phyllopodic; spikes 3 to 8, androgynous, small and few-flowered, roundish, sessile, contiguous or the lower ones remote, the bracts scale-like or filiform, but much shorter than the inflorescence; scales ovate, acuminate and often mucronate, reddish-brown with green midrib and broad, hyaline margins, about as long as the utricles; utricle shortly stipitate, spreading at maturity, elliptical, plano-convex, wingless, spongious at the base, two-ribbed (the marginal), light brown, scabrous along the upper margins and along the short, but distinct, bidentate beak; stigmata 2.

Carex festiva Dew.

Certain points regarding the supposed identity of our plant with *C. Macloviana* d'Urv. make it necessary to reproduce some of the diagnoses already published. Dewey, the author of the species, described the utricle as follows: "fructibus ovatis oblongis rostratis in apice serrulatis bifidis convexo-planis, squama ovata acutiuscula longioribus," and his specimens came from Bear Lake and the Rocky Mountains. This description was by Boott,* somewhat modified, "perigyniis ovato-ellipticis attenuato-rostratis, ore albo-hyalino oblique antice secto demum bidentato, utrinque leviter nervatis"; thus the beak of the utricle at first described as bifid, became by Boott corrected to "obliquely slit on the dorsal face, finally bidentate." The Scandinavian plant is, in accordance with Hartman,† described as possessing a membranaceous, bidentate beak, and the figure given by Andersson‡ shows a similar, bidentate apex of the utricle. Blytt§ attributes a "membranaceously-lobed, truncate beak" to the utricle; thus it seems as if the North American and Scandinavian plants exhibit the same structure in this particular respect, i. e. the beak of the utricle. The Greenland plant of *C. festiva* is by Drejer‖ described as follows: "perigyniis ovato-ellipticis plano-convexis nervosis mar-

* Ill. genus Carex, vol. i, p. 26.
† Skandinaviens Flora 1879, p. 475.
‡ Skandinaviens Cyperaceer 1849, fig. 27.
§ Norges Flora, vol. i, p. 197, 1861.
‖ Revisio crit. Caric. bor., p. 23, 1841.

gine serrulatis rostratis ore hyalino-lobato abscisso." However, in a subsequent paragraph (l. c., p. 24) Drejer calls attention to the fact, that "in *C. festiva* et affinibus os rostri quidem bidentatum est, sed dentes membrana hyalina diaphana conjunguntur, quæ stylo adhuc restante obscuratur ita ut os integrum videatur; stylo autem remoto membrana diaphana facile prætervidetur, quo fit, ut dentes, qui liberi vere non sunt, mere distincti et acutati videantur." Hence that the beak is really not bidentate, but entire on the ventral face by the presence of a transparent membrane. This very structure of the beak being only "apparently bidentate" we have noticed in all the specimens we have examined from Greenland, Scandinavia, Alaska, Vancouver Island and Rocky Mountains from Colorado northward through Canada, and we see no reason for separating these plants from one another. Nevertheless, a recent author, Rev. G. Kükenthal, has reached the conclusion that the Greenland and Scandinavian plants are distinct from the North-American *C. festiva* Dew, but identical with the South-American *C. Macloviana* d'Urv. We have seen no specimen of the latter, which the author, Rev. G. Kükenthal, has described as possessing a "rostrum profunde bidentatum," but this character surely does not apply to the European or Greenland specimens. Mr. C. B. Clarke of Kew has, however, informed us that he prefers to place them all, the South and North-American and European representatives, under *C. Macloviana*, which is an older name than *C. festiva*.

Olney described *Carex Haydeniana** as distinct from *C. festiva* by the long beak of the utricle, a character which is very striking, but hardly sufficient for separating the plant as a species, unless additional characters be observed.

We have proposed a new variety "*decumbens*" which is especially characteristic by the decumbent habit of the plant, somewhat suggestive of *Carex incurva*, besides that the utricle is much larger than in typical specimens of *C. festiva*. This variety *decumbens* has only been observed in the alpine region.

Carex straminiformis Bailey.

Rhizome loosely cæspitose with light brown, persisting sheaths; leaves relatively broad, flat, scabrous along the margins, shorter than the culm; culm erect, from 25 to 37^{cm} in height, quite stout, trigonous, nearly glabrous, leafy at the base, phyllopodic; spikes 3 to 4, gynæcandrous, dense flowered, ovoid, sessile, contiguous, forming a compact head about 2^{cm} in length and 1·5^{cm} in width; scales oblong, acute, light brown with green midrib (of 3 veins) and broad, hyaline margins,

* Clarence King: Report Geol. Explor. 40th Paral. 1871, p. 366.

much narrower and shorter than the utricle; utricle almost sessile, erect, compressed, broadly ovate with very conspicuous, denticulate wings and 4 nerves, of which the marginal ones are very prominent on the ventral face, light green, tapering into a rather long, bidentate, scabrous beak; stigmata 2.

Carex alpina Sw. var. *Stevenii* Holm.

This differs from the type especially by its narrower spikes, which are less contiguous and often somewhat remote and peduncled; the utricle is at maturity dark, reddish brown with an emarginate beak, scabrous along the margins and early deciduous; the scales are brownish to almost black, with narrow, hyaline margins; in specimens from dry rocks the culms are seldom more than from 6–12^{cm} in height, but in specimens from swamps the culms attain a height of 55^{cm} and are much more slender than in the type.

Carex melanocephala Turcz.

C. nigra Olney Exsicc., fasc. 5, 24, 1871.
C. atrata L. var. *nigra* Am. auth.
C. nova Bailey.*

Turczaninow described this species in his work Flora Baicalensi-Dahurica with the following diagnosis: "Spicis 3 dense congestis sessilibus, adjecta rarius quarta subremota breviterque pedunculata, terminali androgyna basi mascula, reliquis fœmineis, utriculis glabris ellipticis dorso convexis subtrigonis, rostro longiusculo bidentato terminatis; radice stolonifera. In alpibus Baicalensibus Urgudei, Schibet, ad fl. Tessa et cæt. Floret Junio, Julio." Boott has, also, described *C. melanocephala*, but as a variety "*parviflora*" of *C. alpina:* "perigyniis majoribus ellipticis, bifidis, enerviis, fusco-purpureis, basi pallidis, squama ovata fusco-purpurea nervo concolori rarius extra apicem producto longioribus." The species has for many years been collected in this country, but has been confounded with *C. nigra* All. and with *C. alpina* Sw., while Professor Bailey segregated it as an independent species *C. nova.* The diagnosis of *C. nova* is, however, very incomplete, and since we have had the opportunity of studying an abundance of specimens at various elevations, we have thought it worth while to append a diagnosis of this interesting species, which Mr. C. B. Clarke has kindly identified for us as identical with Turczaninow's *C. melanocephala:* Rhizome loosely cæspitose with ascending shoots, the leaf-sheaths persisting, reddish brown; leaves shorter than the culm, relatively narrow, but flat, scabrous along the margins and lower face, the ligule

*Jour. Botany London, 1888, vol. 26, p. 322 and Mem. Torr. Bot. Club, vol. 1, 1889, p. 10.

very distinct; culm erect, stout, triangular, scabrous especially above, from 9 to 68^{cm} in height (the smallest specimens having been collected on Long's Peak, Mt. Elbert and Gray's Peak at 12,000 ft. alt.), leafy at the base, phyllopodic; spikes 2 to 4, but mostly 3, roundish and sessile, forming a dense, oval or roundish head, very seldom the lowest remote; the bracts very short, scale-like or the lowest one extended into a short bristle, much shorter than the spike; the terminal spike gynæcandrous, the lateral purely pistillate; scales ovate, acute to acuminate, dark purple with pale midrib, shorter than the utricle; utricle sessile, plano-convex, varying from broadly elliptical to roundish, granulated, glabrous or minutely denticulate along the upper margins, two-nerved (the marginal), spreading at maturity, yellowish and purplish spotted to almost black when mature, terminated by a beak of variable length, emarginate to bidentate; stigmata 3, seldom 2.

In high alpine specimens the utricle becomes wholly glabrous and the beak longer, and it was in such plants that the number of stigmata was observed to be, sometimes, only two.

Carex chalciolepis sp. n. (figs. 1–5).

Rhizome cæspitose, the leaf-sheaths persisting, purplish or brown; leaves shorter than the culm, relatively narrow, but flat, erect, scabrous along the margins; culm slender and weak, often reclining, triangular, scabrous or nearly glabrous, leafy at the base, from 17 to 75^{cm} in height, (the tallest being those from Pagosa Peak), phyllopodic; spikes 3 to 4, dense-flowered and thick, from 1 to 1·5^{cm} in length and 1^{cm} in thickness, shining brown, "copper-colored," contiguous, sessile or the lowest very shortly peduncled and subtended by a short, filiform bract, the other bracts merely scale-like; an empty, sheathing and foliaceous bract is nearly always observable in some distance, varying from 2 to 6^{cm} below the inflorescence; scales of staminate flowers varying from lanceolate and acute (fig. 1) to elliptical; scales of pistillate flowers ovate and acuminate (fig. 2) or elliptical oblong to lanceolate (fig. 4), narrower, but longer than the utricle, dark purplish or reddish brown with the apex and margins more or less hyaline, but with the midrib seldom visible; utricle sessile, erect, ovoid (fig. 3) or almost orbicular (fig. 5), slightly plano-convex, granulated, two-nerved (the marginal), minutely scabrous along the upper margins, yellowish green with purplish spots or uniformly dark-colored, terminated by a short, emarginate to bidentate beak; stigmata 3.

The accompanying figures illustrate the scales and utricles of *C. chalciolepis* from Pagosa Peak (figs. 1–3), and Mt. Kelso (figs. 4–5), while fig. 6 represents the utricle with the scale of

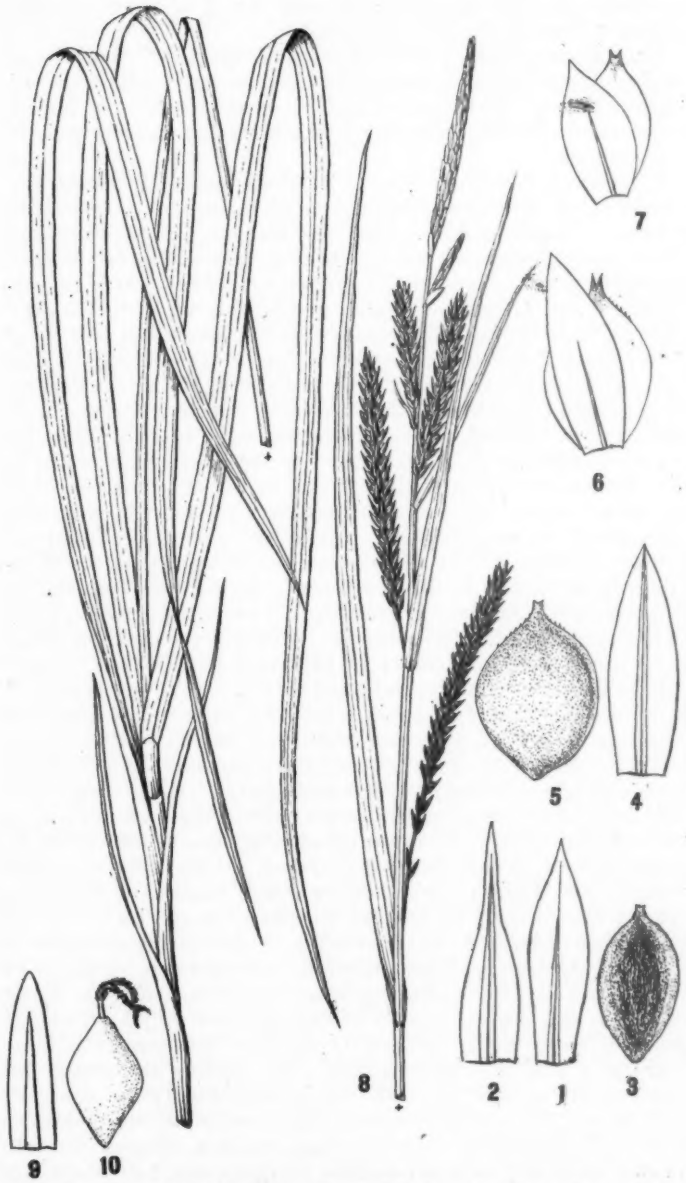


Fig. 1. *Carex chalciolepis* from Pagosa Peak, scale of staminate spike; fig. 2, scale of pistillate spike; fig. 3, utricle; fig. 4, scale of pistillate spike, and fig. 5, utricle of the same species from Mt. Kelso. Figs. 6 and 7, utricle and scale of *C. atrata* from Long's Peak and Norway. Fig. 8, *C. rhomboidea* natural size; figs. 9 and 10, scale and utricle of same.

C. atrata L. from Long's Peak, and fig. 7 the utricle and scale of *C. atrata* from Norway.

Having proposed *C. chalciolepis* as a species distinct from *Carex atrata* L., and having studied a large collection of representatives of the latter and its nearest allies in North America, we feel induced to present some data concerning their characteristics.

As indicated in the synopsis of the species, *C. atrata*, the typical plant, occurs on some of the high mountains of Colorado, but seems, however, to be rare. In speaking of the "typical plant" we might state at once, that this is very seldom recognized in this country, and is excluded altogether in Professor Macoun's Catalogue of Canadian plants, where the variety "*ovata*" (Rudge) Boott is the only one that is enumerated as occurring between the Atlantic coast and the Rocky Mountains. A like disposal is suggested in Gray's Manual (1890), where the variety *ovata* is credited to the White Mountains, New Hampshire, Vermont and northward, with no mention of the typical plant. It is very likely tha Rudge's *C. ovata* is the predominant form in the northeastern parts of this continent, but it is not the only one in the north, since the type has been collected in southern Greenland, on mountains at "Kicking Horse Lake" and on "Sheep Mountain" in the British provinces, besides in Wyoming, Montana and Utah.—Linnæus is the author of *C. atrata*, and he described it from Lapland specimens, the diagnosis, brief as it may seem, being nevertheless sufficient for distinguishing the species from the others in his Flora Lapponica: "*Carex* spicis ad apicem culmi pendulis androgynis"; by "androgynis" is naturally meant "gynæcandrous," since the spikes bear the pistillate flowers at the apex, the staminate ones at the base. But, strange to say, very few authors have since described the species in the same way "spicis androgynis," while they have referred the androgynous character only to the terminal spike, and this deviation from the original diagnosis is noticeable in the works of Wahlenberg, Andersson, Blytt, Hartman, Treviranus and Koch; on the other hand, Lightfoot, Schkuhr, Kunth, Gaudin and Boott have described the species in accordance with Linnæus as possessing "several gynæcandrous spikes." Otherwise the European authors seem to agree in respect to the general characterization of the species, the shape of the spikes, the scales, utricle, etc., and we might point out some of these characteristics for further comparison with its European and American allies. The spikes are mostly all gynæcandrous, and the terminal is oval, the lateral more or less oblong; they are borne on rather stout peduncles, which are almost glabrous; the scales are ovate, acute to obtuse, blackish-brown with very narrow, hyaline margins, and a little shorter

than the utricle; this organ is ovate, compressed trigonous, granulated, two-nerved (the marginal), and abruptly terminated by a short, emarginate to bidentate beak; the color of the utricle is light green, but changes often to brownish and purple-spotted at maturity. A variety "*spadicea*," with the scales and utricles grayish-brown, is described by Beurling from the mountains of Norway.*

Among the nearest allies of *C. atrata* in Europe may be mentioned *C. nigra* All. and *C. aterrima* Hppe., both of which seem confined to the Pyrenees, the "Alps" of Switzerland and Austria. In the former of these the spikes are nearly sessile and ovate, the utricle is reddish-brown, when young, becoming dark purplish at maturity, and is prominently scabrous along the upper margins; while in *C. atrata* the granulation is only represented by roundish projections; *C. aterrima*, which looks more like *C. atrata*, is quite robust, with the spikes oblong—cylindrical, peduncled, and the utricle is merely granulated, but purplish-black with greenish base and margins. Of these the former is by most authors considered distinct from *C. atrata*, while *C. aterrima* is frequently enumerated as a mere variety of this from higher elevations and with a later time of flowering. But even if *C. aterrima* be a good species, *C. atrata* does, nevertheless, occur in Europe, with narrow, cylindrical spikes of variable color, from almost black to reddish-brown. This variation in color and shape of spikes may sometimes be so pronounced that the European *atrata* seems to pass over into the American *C. ovata* Rudge.

As already stated, typical *C. atrata* occurs in this country, but judging from the collections which we have studied, it does not seem to be as frequent as the so-called *C. ovata* Rudge. The principal characteristics of this plant are in accordance with Rudge, the gynæcandrous spikes being ovate and pendulous, the ovate, acute scales of a fuscous color. A number of Canadian specimens demonstrate a habit somewhat different from that of *C. atrata vera*, not only by the larger and narrower spikes of a dark, reddish color, but also by the long peduncles, which are very slender and prominently scabrous. *C. ovata* is altogether a much more graceful plant than *C. atrata*, and may, perhaps, represent a species distinct from *C. atrata*. But *C. ovata*, *C. nigra* and *C. aterrima* were with Boott only varieties of *C. atrata* L.

In comparing these plants with our *C. chalciolepis* it is readily seen that this is at once distinguished by its dense, cæspitose growth, the very slender, glabrous culms, which are more or less reclining, and by its usually sessile, contiguous,

* Caricum Scandinaviæ conspectus. (Bot. Notiser 1853, p. 36.)

Fig. 11, *Carex chimaphila*, natural size; figs. 12 and 13, utricle and scale of same. Fig. 14, *C. acutina* var. *petrophila*, natural size.

dense-flowered spikes with shining, copper-colored scales and utricles. The larger size of the scales in proportion to the utricles is very characteristic. It is a plant not easily confounded with typical *C. atrata* or *ovata*, and we do not feel inclined to merge it with the others as a mere form or variety of *C. atrata*.

Besides *C. ovata* and *chalciolepis* there is still a third plant in the Rocky Mountains, which also exhibits a close affinity to *C. atrata*, the so-called *C. bella* Bailey. This plant possesses much narrower spikes than any of the preceding; the peduncles, especially of the lower spikes, are very long and slender, prominently scabrous, and the scales are dark purplish with broad, light green midrib and very broad, hyaline margins, and are a little shorter than the membranaceous, somewhat inflated, pale green utricle, of which the two marginal nerves are quite thick and conspicuous. In this species the utricle exhibits only a minute granulation and lacks the scabrous margins, a structure which in many respects is suggestive of that of *C. Mertensii* Prescott. We have, thus, before us another type of the *Carex atrata* alliance which shows transition to one of the most evolute forms of the *Melananthæ: C. Mertensii*, and it appears as if the typical *C. atrata* may be considered as constituting the fundamental species of a series of types, some characteristic of Europe alone: *C. nigra* and *aterrima*, and others of this continent: *C. ovata*, *chalciolepis*, *bella* and *Mertensii*.

Carex Parryana Dew.

The distribution of the sexes seems very variable in this species and we have observed diœcism in several individuals. The terminal spike is very often gynæcandrous, while the lateral, when such are developed, are purely pistillate; in monostachyous specimens the spike is mostly gynæcandrous or in a few cases pistillate only. Mono- and di-stachyous culms frequently occur on the same individual.

Carex chimaphila sp. n. (figs. 11–13).

Rhizome loosely cæspitose with short, ascending stolons, the leaf-sheaths persisting, purplish or dark brown; leaves relatively broad, flat, a little scabrous along the margins, shorter than the culm; culm erect, slender, triangular, scabrous, from 12 to 30^{cm} in height, phyllopodic; spikes 3 to 4, mostly 3, contiguous or the lowest one remote, subtended by black, scale-like bracts without sheaths, the lowest sometimes with a blade, shorter than the inflorescence; terminal spike staminate, short and clavate, peduncled, the scales spatulate, brown to almost black with pale midrib; lateral spikes pistillate, from 1 to 1·5^{cm}

in length, dense-flowered, all, especially the lowest, peduncled, erect; scales (fig. 12) lanceolate, acuminate, spreading, blackish purple with hyaline apex and very short and inconspicuous midrib, the scale narrower, but longer than the utricle; utricle (fig. 13) sessile or minutely stipitate, spreading, roundish, compressed, granulated, two-nerved, sparingly scabrous along the upper margins, dark green with purplish spots especially above, terminated by a short, entire or subemarginate beak; stigmata 2; style exserted, but short.

This species, to a certain extent, has the aspect of some members of the *Aeorastachyæ*, *C. cryptocarpa* for instance, but seems, nevertheless, to be more naturally allied to the *Microrhynchæ*, and its place may be defined as near *C. hyperborea* Drej., but diverging from this by the long and spreading scales.

Carex variabilis Bailey.

Rhizome stoloniferous with persisting, light-brown to purplish sheaths; leaves flat, relatively broad; scabrous along the margins, as long as the culm or longer; culm erect, stiff, triangular, scabrous especially below the inflorescence, from 10 to 45^{cm} in height, phyllopodic; spikes from 3 to 6, contiguous or the lowest one remote, the terminal and uppermost lateral ones staminate, the others pistillate or, sometimes, androgynous, erect, sessile or the lowest peduncled; a pistillate spike is often developed from the axil of one of the basal leaves, borne on a very slender peduncle to the length of 12^{cm} in length; bracts of the inflorescence leaf-like about as long as the inflorescence or the uppermost ones shorter, but without sheaths; staminate spike broadly linear; the pistillate, cylindrical, obtuse, dense-flowered except towards the base (from 2 to 5·5^{cm} in length); scale of staminate flower spatulate oblong and obtuse, light purplish with hyaline apex and midrib; scale of pistillate flower ovate to elliptical, acute, dark purplish to almost black with green, not excurrent midrib, shorter and narrower than the utricle; utricle sessile, light green, granulated, two-nerved (the marginal), obovate to broadly elliptical, compressed, terminated by a short, entire, purplish or green beak; stigmata 2.

var. *sciaphila* nob.

Culms from 25 to 42^{cm} in height, very slender and reclining; spikes very short and mostly remote, otherwise as the type.

Carex acutina Bailey.

Rhizome cæspitose with persisting, purplish or brownish sheaths; leaves quite broad and flat, scabrous along the margins, as long as the culms or longer; culm erect, stiff, triangu-

lar, scabrous, from 50 to 75^{cm} in height, phyllopodic; spikes 4 to 6, contiguous or the lowest one remote, erect or sometimes spreading, the upper ones sessile, the lower ones short-peduncled; the terminal and uppermost lateral spikes staminate, the others pistillate or androgynous, subtended by sheathless foliaceous bracts, of which the lowest exceeds the inflorescence, the others being shorter; staminate spike linear, the scales oblong-lanceolate, reddish-brown with pale, not excurrent midrib; pistillate spike from 3 to 4^{cm} in length, quite thick, cylindrical, obtuse, the scales ovate-lanceolate and acuminate, dark brown to almost black with the midrib obsolete, longer, but narrower than the utricle; utricle stipitate, oval to elliptical, compressed, granulated light green, two-nerved, the beak short, entire, purplish around the orifice; stigmata 2.

var. *petrophila* nob. (fig. 14).

Culms very low, from 7 to 15^{cm} in height; spikes until 6^{cm} in length, very narrow, but dense-flowered, attenuated at the base, contiguous, the lower ones often very long-peduncled; utricle stipitate, almost roundish in outline with a short, entire beak.

Carex rhomboidea sp. n. (fig. 8–10).

Rhizome loosely cæspitose, the sheaths persisting, light purplish; leaves rather narrow, but flat, scabrous along the margins, a little shorter that the culm; culm 30 to 40^{cm} in height, erect, slender, triangular, scabrous, phyllopodic; spikes 3 to 5, the terminal and, sometimes, the uppermost lateral staminate, the others pistillate, or the uppermost lateral androgynous, erect, sessile or the lowest one short-peduncled, mostly contiguous, subtended by foliaceous, sheathless bracts with blades as long as the inflorescence or shorter; staminate spike linear, the scales spatulate oblong, obtuse, light reddish-brown with pale midrib and hyaline margins; pistillate spikes very dense-flowered, cylindrical, attenuated at the base, from 1·5 to 4^{cm} in length, the scales (fig. 9) dark purplish with white, broad midrib, oblong, obtuse, narrower, but longer than the utricle; utricle sessile, elliptical, rhomboid (fig. 10) granulated, light green, two-nerved, compressed, entirely beakless; stigmata 2.

Carex variabilis, *C. acutina* and *C. rhomboidea* constitute a small group of *Microrhynchæ* of which the two first show some approach to the old world types of the *aquatilis* group, though very distinct from this; *C. rhomboidea* stands somewhat isolated among the other *Microrhynchæ*, but belongs undoubtedly to this section, and perhaps to the group, the center of which is Boott's *C. angustata*.

Carex Rossii Boott.

It is strange to see how often vegetative characters are overlooked by systematic writers. The structure of the rhizome for instance is very seldom studied, and by looking at the plant descriptions in the last edition of Gray's manual, in the Synoptical Flora and other more recently published works, it is too evident that this part of the plant might have been considered and studied much more carefully. Even in such inconspicuous and uniform looking plants as our *Carices* does the structure of the rhizome, of the leaves and the culms afford good characters for distinguishing closely allied species, and sometimes easier than the structure of the utricle, or the scales. And the fact that the vegetative characters have been left out altogether in descriptive works upon *Carex* has resulted in mistakes, that could easily have been avoided.

One writer* has for instance stated that the European *Carex pilulifera* is identical with the North American *C. communis* (*C. varia* of many authors), by presenting an elaborate table of measurements of spikes, of the distance between these, of the length of the utricle, of the beak, etc., etc., but overlooking the fact that *C. pilulifera* is phyllo-, *C. communis* aphyllo-podic, not speaking of the extremely different habit possessed by these species, when studied "in the field." A similar disposal has been made† of Horneman's *C. deflexa* and Boott's *C. Rossii*, in this way that *C. deflexa* is enumerated as the type of a species with four varieties, *Deanei*, *media*, *Rossii* and *Boottii*. Of these *C. Rossii* is the only one which occurs in Colorado, and a study of this plant has led us to the belief that it is specifically distinct from the Greenland *C. deflexa*, as Boott himself considered it to be. The latter species we have had the opportunity to observe in a living state in Greenland, and it never appeared to us, when we found the former, *C. Rossii*, in Colorado, that they should represent the same species. There is, among other characters, exactly the same and very conspicuous distinction noticeable in *C. Rossii*, when compared with *C. deflexa*, as we have described above between *C. pilulifera* and *C. communis: C. Rossii* is aphyllo-, *C. deflexa* phyllo-podic.

To fully emphasize the importance of this character, it is, of course, necessary to study a number of specimens collected at different seasons, and to compare the different shoots, floral and vegetative, and their leaves. But besides this distinction derived from the shoots, the structure of the rhizome itself deserves, also, some attention. Thus is the rhizome of *C.*

* M. L. Fernald in Contrib. Gray Herb., vol. xxii, p. 503, 1902.
† L. H. Bailey in Mem. Torrey Bot. Club., vol. i, p. 43, 1889.

deflexa very slender, horizontally creeping and stoloniferous, but producing a number of shoots every year as if it were really cæspitose; each shoot develops only leaves during the first year, succeeded by a terminal, flower-bearing culm the year following. In *C. Rossii* there is, also, a number of shoots from each rhizome, but the shoots are either purely floral or vegetative; moreover the rhizome is much more robust, relatively shorter and ascending, not horizontal, and not stoloniferous in the stricter sense of the word. In considering the other parts of the plants, we might mention that the utricle in *C. deflexa* is very shortly beaked, and the beak bifid, while this organ in *C. Rossii* is extended into a very prominent, bidentate beak; the diagnosis as reproduced (l. c.) is, altogether, not very correct.

C. The Geographical Distribution of the Carices of Colorado.

In the accompanying table the species which are marked by an asterisk prefixed are exclusively confined to the bare exposures above the timber-line and are, thus, truly alpine; they number fifteen, and to these may be added the variety *decumbens* of *C. festiva*. Several of the others are, also, to some extent alpine, but have occasionally been observed below the timber-line on some of the mountains; among these, are, for instance: *C. melanocephala*, *C. scopulorum* and *C. capillaris*. Of these the two former are most abundant just at timber-line, while *C. capillaris* is more frequent at lower elevations, where it reaches a more luxuriant growth than higher upward.

Besides this distribution shown in the table given below, the following species have been reported from

China: *C. stellulata, stenophylla, incurva, atrata, vulgaris, rigida, rupestris* and *microglochin.*
Japan: *C. canescens, siccata, Buxbaumii, vulgaris* and *pyrenaica.*
South America: *C. canescens* (Argentina–Tierra del Fuego), *marcida* (Patagonia), *festiva* (Argent.–T. del. Fuego), *incurva* (Peru–T. del. Fuego) and *vulgaris* (Chile).
Sandwich Islands: *C. festiva.*
New Zealand: *C. stellulata, teretiuscula, vulgaris* and *pyrenaica.*
Spitzbergen: *C. incurva, nardina, misandra, rupestris* and *pulla.*

And if we examine the highest altitude reached by some of these arctic-alpine species in the Himalayan Mountains, the following may be recorded: *C. microglochin* from 11,000 to 15,000 ft., *canescens* until 12,000 ft., *rigida* 13,000 ft., *alpina* 15,000 ft., *incurva* 15,500 ft. and *atrata* 17,000 ft.

Species of *Carex* in Colorado.	North America.					Europe.				Asia.				
	Rocky Mts. of Canada.	Coast of Alaska.	Arctic region.	Atlantic slope.	Greenland.	North Europe.	Alps and Pyrenees.	Ural.	Caucasus.	Arctic Siberia.	Altai Mts.	Bajkal Mts.	Himalaya.	Kamtschatka and Sachalin.
canescens	+	+	+	+	+	+	+	+	+	+	+	+	+	+
tenella	+	--	--	+	--	+	--	--	--	--	--	--	--	+
**nardina*	+	+	+	--	+	+	--	--	--	--	--	--	--	--
Deweyana	+	--	--	+	--	--	--	--	--	--	--	--	--	--
gynocrates	+	+	+	+	+	?	--	--	--	--	--	--	--	+
stellulata	+	+	--	+	--	+	+	+	+	--	+	--	--	--
occidentalis	.	--	--	--	--	--	--	--	--	--	--	--	--	--
Hookeriana	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Hoodii	+	--	--	--	--	--	--	--	--	--	--	--	--	+
marcida	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Sartwellii	+	--	--	+	--	--	--	--	--	--	--	--	--	--
Douglasii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
teretiuscula	+	--	--	+	--	+	+	--	--	--	--	--	+	--
fœtida	--	--	--	--	--	--	+	--	--	--	--	--	--	--
stenophylla	+	--	--	--	--	--	+	--	+	--	+	+	+	--
athrostachya	+	--	--	--	--	--	--	--	--	--	--	--	--	--
festiva	+	+	+	--	+	+	--	--	--	--	--	--	--	+
**petasata*	+	+	--	--	--	--	--	--	--	--	--	--	--	--
pratensis	+	--	--	+	+	--	--	--	--	--	--	--	--	--
siccata	+	--	--	+	--	--	--	--	--	--	--	+	--	+
Liddonii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
**Bonplandii*	+	--	--	--	--	--	--	--	--	--	--	--	--	--
straminiformis	--	--	--	--	--	--	--	--	--	--	--	--	--	--
**incurva*	+	+	+	--	+	+	+	--	+	+	--	--	+	--
alpina	+	+	+	--	+	+	+	+	--	--	+	+	+	--
melanocephala	--	--	--	--	--	--	--	--	+	--	+	+	--	--
**atrata*	+	--	--	--	+	+	+	+	+	--	+	+	+	--
**chalciolepis*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
bella	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Parryana	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Buxbaumii	+	+	--	+	+	+	+	+	--	--	+	+	--	+
vulgaris	+	+	--	+	+	+	+	--	+	--	--	--	+	--
**rigida*	+	+	+	+	+	+	+	+	+	+	+	+	+	+
scopulorum	--	--	--	--	--	--	--	--	--	--	--	--	--	--
**chimaphila*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
variabilis	+	--	--	--	--	--	--	--	--	--	--	--	--	--
acutina	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Nebrascensis	+	--	--	--	--	--	--	--	--	--	--	--	--	--
rhomboidea	--	--	--	--	--	--	--	--	--	--	--	--	--	--
aurea	+	--	--	+	--	--	--	--	--	--	--	--	--	--
Torreyi	+	--	--	+	--	--	--	--	--	--	--	--	--	--
polytrichoides	+	+	--	+	--	--	--	--	--	--	--	--	--	--
Geyerii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
**filifolia*	+	--	--	--	--	--	--	--	--	--	--	--	--	--
**elynoides*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
**rupestris*	+	--	+	--	+	+	+	+	+	+	--	--	--	--
obtusata	+	--	--	--	--	+	+	+	+	--	+	+	--	--
nigricans	+	+	--	--	--	--	--	--	--	--	--	--	--	--
**pyrenaica*	+	+	--	--	--	--	+	--	+	--	--	--	--	--
**misandra*	+	+	+	--	+	+	+	+	--	+	--	--	--	+
scirpoidea	+	+	+	+	+	+	--	--	--	--	--	--	--	+

TABLE (continued).

Species of *Carex* in Colorado.	North America.					Europe.				Asia.				
	Rocky Mts. of Canada.	Coast of Alaska.	Arctic region.	Atlantic slope.	Greenland.	North Europe.	Alps and Pyrenees.	Ural.	Caucasus.	Arctic Siberia.	Altai Mts.	Bajkal Mts.	Himalaya.	Kamtschatka and Sachalin.
oreocharis	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Pennsylvanica	+	--	--	+	--	--	--	--	--	--	--	--	--	--
Rossii	+	--	--	--	--	--	--	--	--	--	--	--	--	--
umbellata var. *brevirostris*	+	--	--	--	--	--	--	--	--	--	--	--	--	--
viridula	+	--	--	--	--	--	--	--	--	--	--	--	--	--
lanuginosa	+	--	--	+	--	--	--	--	--	--	--	--	--	--
aristata	+	--	--	--	--	--	--	--	--	--	--	--	--	--
Backii	+	--	--	+	--	--	--	--	--	--	--	--	--	--
capillaris	+	+	--	+	+	+	+	--	+	--	+	+	--	+
longirostris	+	--	--	--	--	--	--	--	--	--	--	--	--	--
microglochin	+	+	+	--	+	+	+	--	+	--	+	--	+	+
**Engelmannii*	--	--	--	--	--	--	--	--	--	--	--	--	--	--
utriculata	+	+	--	+	--	+	--	--	--	--	--	--	--	+
**pulla*	?	+	+	--	+	+	--	+	--	+	--	+	--	+
monile	--	--	--	+	--	--	--	--	--	--	--	--	--	--
rostrata	+	--	--	--	--	--	--	--	--	--	--	--	+	+
lupulina	--	--	--	+	--	--	--	--	--	--	--	--	--	--

The *Carices* of Colorado may, from a geographical viewpoint, be classified in two sections: Northern and Southern.

I. *Northern Species.*

a. Circumpolar types.

C. canescens, incurva, rigida, rupestris, misandra and *pulla.*

b. Arctic, but not circumpolar.

C. nardina, gynocrates, festiva, alpina, atrata, Buxbaumii, scirpoidea, capillaris and *microglochin.*

c. Northern but not arctic types.

C. tenella, stellulata, teretiuscula, pratensis, siccata, Hoodii, vulgaris, obtusata, utriculata and *rostrata.*

d. Northern types, endemic to North America.

C. Deweyana, Hookeriana, marcida, Sartwellii, Douglasii, athrostachya, petasata, Liddonii, Bonplandii, Parryana, variabilis, acutina, Nebrascensis, aurea, Torreyi, polytrichoides, Geyerii, filifolia, nigricans, Pennsylvanica, Rossii, Backii, umbellata, longirostris and *lanuginosa.*

II. *Southern Species.*

e. Species common to both worlds.

C. fœtida, stenophylla, pyrenaica and *melanocephala.*

f. Species endemic to North America.

C. occidentalis, straminiformis, chalciolepis, bella, scopulorum, chimaphila, rhomboidea, elynoides, oreocharis, Engelmannii, monile and *lupulina.*

When comparing the geographical distribution of these *Carices*, the arctic-alpine are of a special interest, because they prove that there are species common to these mountain-peaks and to the polar regions, a fact that may point towards the place where these species originated, or let us say "developed."

And the most natural explanation seems to be, that they are remnants of a glacial flora which were left on these mountains, while the others migrated back to their northern homes, when the ice receded. Their center of distribution would, thus, be the arctic region. This explanation might be plausible in respect to the circumpolar species, but less so concerning the others. For in regard to the latter there is some, and indeed no small, possibility for supposing that these had originally developed in the South, but that they accompanied their arctic brethren on their return to the North. The latter explanation might be applicable especially to such species which are not strictly alpine, but which, nevertheless, are known to occur in the arctic region.

When, thus, the geographical distribution fails to give us any exact information about the center of development of such species which are arctic, but not alpine, some other data may be taken into consideration. We suggest the association with allied species as perhaps giving some clue to the solution of this problem.* Would it not be natural to suppose that where some species is found associated with a group of types which appear to be closely allied to this, that "there" may be sought the center of its distribution, if not of its development? We might illustrate this suggestion by an example, taken from *Carex festiva*. This species is arctic, but neither circumpolar or strictly alpine; it is relatively rare in the polar-regions and occurs there only as what may be termed the "typical" plant. But much farther South and especially in the subalpine zone of the Rocky Mountains is a herd of this same species, accompanied by several aberrant forms, besides by species that are apparently distinct, but among its closest allies: *C. athrostachya, petasata, pratensis*, etc. Judging from our present knowledge

*Compare R. v. Wettstein: Grundzüge d. geogr.-morphol. Methode d. Pflanzensystematik, 1898, p. 35, etc.

of the distribution of this species, *C. festiva*, its geographical center and, also, its center of development seems to have been in the South, in the Rocky Mountains, where it is, thus, typically developed, accompanied by allies and most abundant. And its occurrence in the arctic region may be explained in this way, that individuals of this species were among those that migrated northward with the arctic plants. This instance of an arctic plant having evidently originated in the South may easily be supplemented with others, and there is even among the circumpolar *Carices* from Colorado a species which seems to illustrate the same case: *C. canescens*. This species is also rather rare in the extreme North, while it abounds farther South, associated with more or less deviating forms, besides by close allies. Moreover this species is especially frequent in the lowlands of North and Middle Europe, Central Asia and of the temperate zones of this continent, extending throughout the southern portions of South America to Tierra del Fuego. But it is, of course, impossible to define the original center of a species with such wide distribution as *C. canescens*, with any closer proximity than that the center was evidently in the temperate zone. The remarkable predominance of varieties of *C. canescens* on this continent in contrast to Europe and Asia, might point towards its center as being looked for here, inasmuch as it is here surrounded by such species which we, for morphological reasons, consider as close allies, e. g., *C. vitilis*, *trisperma*, *tenuiflora*, *loliacea* and *tenella*, of which only the first, *C. vitilis*, has reached beyond the arctic circle.

These examples might be sufficient for illustrating the probable southern origin of certain plants that are, also, known as "arctic." But in regard to the other circumpolar *Carices* from Colorado, we are unable to locate the original center of these but in the polar regions. *C. rigida*, *misandra* and *pulla* appear as a matter of fact not only to have their greatest distribution within these regions, but they exhibit, besides, a much more pronounced tendency to develop varieties than they do farther south, where they are relatively very rare. The mono- and homo-stachyous *C. rupestris* and *incurva* lack the plasticity of the hetero-stachyous species and occur only as typically developed, wherever they are found; but their prevalence in the North make us suppose that they originated there. We may for similar reasons attribute a northern and arctic center of distribution to *C. nardina* and *C. microglochin*. But in regard to the other members of the category, "Arctic, but not circumpolar types," we believe that all of these came from stations south of the arctic region. Let us, for instance, consider *C. atrata* and *alpina*. The former is only known as arctic in a few stations of the European continent, while the other has been collected in arctic Russia, Finmark, Greenland

and North America, but is much more frequent farther South. We have called attention to the occurrence of *C. melanocephala* in the mountains of Colorado, where *C. alpina* also occurs, and we have mentioned the presence of two types, which we consider as allies of *C. atrata: C. bella* and *C. chalciolepis*, as inhabiting these same mountains together with *C. atrata*. Furthermore that a third ally of *C. atrata*, *C. ovata*, abounds in the northeastern parts of this continent, thus illustrating the occurrence of allied types associated with each other, which we believe might indicate the location of the center of distribution as being in the Rocky Mountains, as far as concerns the American representatives of *C. atrata* and *alpina*. We have stated, moreover, that *C. atrata* is in Europe, to some extent, accompanied by two plants *C. nigra* and *aterrima*, both of which may be looked upon as immediate allies of this species. And if we extend our comparison of these species with those that occur in the Himalayas, we find there not only typical *C. atrata* and *alpina*, but also some aberrant forms, and some distinct species, among which *C. Lehmannii*, *obscura*, *Duthiei*, *nivalis*, and *psychrophila*, which appear to represent immediate allies of these two species. If thus the association with allies in connection with frequent occurrence and tendency to vary may throw any light upon the question as to their center of distribution or even of development, we believe we are justified in supposing that as far as we know *C. atrata* and *C. alpina* in this particular respect, these species had probably more than one center, and very likely one in the Rocky Mountains, another in the European Alps and a third one in the Himalayas.

The third and fourth category of Northern types emphasize such species as are not arctic; only a very few of these are alpine; *C. petasata*, *Bonplandii* and *filifolia*, and these are, furthermore, endemic to the Rocky Mountains. The remaining species of these same categories are either common to both worlds or endemic to North America and some to the Rocky Mountains alone. *Carex stellulata* is widely distributed throughout the northern hemisphere in the lowlands of the temperate zone; besides that, it occurs in New Zealand. It reaches its highest development on this continent, where it exhibits a vast number of forms, some of which have been segregated as distinct species and is, in the northern provinces, frequently associated with an ally, *C. gynocrates*, which we consider as representing a *forma hebetata* of the section *Astrostachyæ*. *C. gynocrates* does not seem to occur in Siberia, but its homologue, *C. Redowskyana*, has been reported from several stations of that country, where, however, *C. stellulata* is absent, at least in the northern parts. The European *C. stellulata* shows no tendency to vary, but the fact that it is associated with such

species as *C. diœca* and *Davalliana*, both of which appear to represent lower types of the section (*Astrostachyæ*), makes us believe that there is both an American and an European center of its distribution and development. *Carex tenella* shows a similar wide distribution on this continent from the Atlantic slope to Alaska, associated with such near allies as *C. canescens*, *loliacea*, *tenuiflora*, etc., all of which are, also, known from Scandinavia; hence we might conclude that they originated from two centers, one in Scandinavia and another one in the northern Rocky Mountains.

Among the species of this category, which we suppose were developed in the Rocky Mountains, but which took part in the migration northward with the arctic plants on their return, may be mentioned *C. pratensis*, of which the very isolated occurrence in South Greenland does not seem explainable in any other way. The almost cosmopolitan *C. vulgaris* is difficult to locate, inasmuch as it is generally accompanied by several allied types, wherever it occurs in the mountains or lowlands. We can only say that it does not belong to the arctic region, and that the diversity of types into which it has developed, for instance in the Himalayan Mountains, in Scandinavia and in the northwestern parts of this continent, indicates several local centers.

In regard to the other types, the majority of these are endemic to North America and several to the Rocky Mountains, where they have, naturally, developed.

The second category, "Southern types," contains a few species common to both worlds, among which *C. pyrenaica* shows a remarkable wide distribution: from Colorado to the British provinces, Alaska, the Pyrenees and Alps of Switzerland, Caucasus, Japan and New Zealand, while its nearest ally *C. nigricans* is confined to the Rocky Mountains and Alaska and *C. macrostyla* to Spain and the Azores. *C. fœtida* is only known from Colorado, California and the Alps of Switzerland. *C. stenophylla* follows the Rocky Mountains throughout Canada, and is known also from Southern Europe, Caucasus, Altai, Bajkal, Himalayas and China. The geographical center of *C. nigricans* may, beyond doubt, be sought in the Rocky Mountains, while it seems impossible to locate that of *C. pyrenaica*, unless there may have been at least two centers, one in the Rocky Mountains and another in the old world, Europe or Asia; its occurrence in New Zealand can not be accounted for with any satisfaction. In regard to *C. fœtida* we feel unable to explain its distribution in any other way than by admitting two centers, the Rocky Mountains and Switzerland Alps. And if we consider *C. stenophylla*, there seems no possibility of defining its center with any proximity neither in this country or in the old world.

Among the southern types that are endemic to this con-

tinent are some alpine species: *C. elynoides*, *Engelmanni*, *chalciolepis*, *chimaphila*, *scopulorum* and *bella*. We have already discussed the distribution of *C. chalciolepis* and *bella*, both of which show affinities to *C. atrata*. In regard to *C. scopulorum* this is undoubtedly a southern type, but has, however, spread farther North to Wyoming and Montana, but is not reported as being frequent. *C. elynoides* is hardly to be considered as a rare species, since its great resemblance to *Elyna spicata* may have caused it to be confounded with this, besides that relatively few species of *Carex* are represented in the herbaria from the higher alpine regions of these mountains.

There is thus quite a number of Carices in Colorado endemic to this country, and although these are not of so much interest from a geographical viewpoint as the northern, common to both worlds, they will, no doubt, prove valuable to the study of homologues, such as many of these actually are, of old world species.

Considering the arctic species, which are, also, occurring in Colorado, we have demonstrated the possibility of some of these having originated in the arctic region: *C. incurva*, *rigida*, *rupestris*, *misandra*, *pulla*, *nardina* and *microglochin*. Not less than five of these are, also, circumpolar and it seems as if the existence of these, together with *C. nardina* and *microglochin*, indicate that the Rocky Mountains harbor a certain element of that flora, which we call the arctic, which was reared in the polar-regions, but forced south during one of the greatest revolutions in the history of the earth, known as the glacial epoch. Some of the other *Carices* which we have enumerated from Colorado are, also, arctic, but neither circumpolar or having originated in the extreme North, as far as we know, for instance *C. atrata*, *alpina*, *festiva*, *scirpoidea* and *gynocrates*, and these illustrate a flora partly of American, partly also of old world origin. Most of the others are truly American types, and evidently young types.

If it had been within the scope of the present paper to consider other genera than *Carex*, as represented in Colorado and in the arctic region, we would have been able to offer further evidence of the existence of a glacial flora in the Rocky Mountains, easily illustrated by a number of other types, such as *Dryas octopetala*, *Silene acaulis*, *Campanula uniflora*, *Saxifraga nivalis*, *cernua* and *flagellaris*, *Lloydia serotina* and many others. But when we undertook the task of discussing the geographical distribution of the genus *Carex* in Colorado and quite especially that of the alpine types, it was simply the writer's intention to make an attempt to show, that even a single genus of plants might offer some tangible proof of the foundation of the theory relating to the history of arctic plants, as demonstrated in the writings of the Swedish naturalist A. G. Nathorst.

Brookland, D. C., December, 1902.

ART. IV.—*Chrysocolla: A Remarkable Case of Hydration;* by CHARLES M. PALMER.

SOMEWHAT over a year ago a quantity of medium grade oxidized copper ore from Pinal County, Arizona, came into the writer's hands, with the information that it was representative of the class of ore that was being shipped to the smelters, and that as the latter were claiming the presence of surprisingly large quantities of moisture, sometimes as high as 16 or 17 per cent, it seemed to be a matter for investigation. The ore consisted mostly of bluish or greenish chrysocolla impregnating or filling seams in a siliceous matrix, and occasionally as an incrustation; sometimes, however, being associated with a black variety containing considerable manganese.

Water determinations were made on several lots which gave results varying from about 17 to 20 per cent, which, for an air-dried ore carrying but 12 or 14 per cent of copper, was somewhat unexpected and remarkable. Then several large pieces of enamel-like turquoise blue chrysocolla were picked out, which seemed to be comparatively pure, and these were powdered preparatory to analysis (sample No. 1) with the view of getting more light on the character of the mineral. One gram was weighed out on a watch glass one evening and placed in a dessicator over concentrated sulphuric acid. The next day upon weighing for determining the loss under these conditions and finding it, according to my weights, to be over 12 per cent, I thought I had simply made one of those unaccountable mistakes in my weights that will sometimes happen, and therefore promptly weighed out another portion, which gave practically the same result. The material gave the following upon analysis:

Silica (insoluble)	38·64%
Cupric oxide	25·22
Alumina	11·76
Ferric oxide	trace
Water (over H_2SO_4)	12·36
Water (additional loss at red heat)	12·22
	100·20

An effort was made to obtain a purer specimen, and from a lot of ore from another locality in Arizona, another sample (sample No. 2) of deep blue chrysocolla, apparently pure and perfectly homogenous in appearance, was carefully picked out. It lost 18·24 per cent after 22 hours in a dessicator over sulphuric acid, which loss was increased only to 18·96 per cent after 33 days

more, and to 19·60 per cent after 24 hours at 100° C. After this, the platinum dish containing the substance was allowed to sit in the balance case for 48 hours, during which time it not only regained all its previous loss but 0·68 per cent in addition, and all this, too, without a perceptible change in color or general appearance.

The total loss by heating at a low red heat to constant weight was 27·28 per cent. Analysis of the sample gave the following results:

Silica	35·84%
Cupric oxide	31·50
Alumina	3·74
Ferric oxide	trace
Manganese oxide	"
Calcium oxide	1·76
Magnesium oxide	0·16
Water (over H_2SO_4)	18·96
Water (at low red heat)	8·32
	100·28

Another sample (No. 3) of dark green material from the Pinal ore was found, which occurred as an incrustation about one-eighth of an inch thick, and which appeared no less pure and even richer in copper than the last. It lost 15·60 per cent over sulphuric acid in 24 hours, this being increased after 11 days to 20·54 per cent. The dish containing the substance was then placed in a dessicator over water. In 21 hours it had made up all its former loss and 2·64 per cent besides, and after four and one-half days more under the same conditions, this increase amounted to 5·14 per cent, making a variation of 25·68 per cent in the amount of water at ordinary temperature with no change whatever in appearance. The loss at 100° C. was 20·72 per cent, being but very little higher than the loss over sulphuric acid, and the total loss at a red heat was 29·14 per cent. The analysis of this material, of which only about 1·5 grams were obtainable, is as follows (calcium and magnesium being present but not determined quantitatively):

Silica	33·28%
Cupric oxide	30·76
Alumina	4·60
Ferric oxide	trace
Manganese oxide	trace
Calcium oxide	not det.
Magnesium oxide	not det.
Water (over H_2SO_4)	20·54
Water (at low red heat)	8·60
	97·78

These samples began to change color at the temperature of the sand bath and at red heat turned black. Treatment of this black residue with acids, and even prolonged and repeated fusion with potassium bisulphate, failed to bring all the copper in solution. Sodium carbonate fusion was not tried.

The most remarkable feature of the whole affair is that a mineral or chemical compound should occur in nature with such a large amount of water so loosely attached to its molecular structure. Chrysocolla not being a crystalline mineral, the loss of water of crystallization is not indicated by the loss of crystalline form, and neither is there a change of color upon the loss of the very portion that would ordinarily be regarded as water of crystallization. Diligent search of the literature of hydrous minerals in general, and chrysocolla in particular, accessible to the writer, failed to indicate that any such unusual behavior has been previously noticed. Heretofore, a loss of 2 or 3 per cent over sulphuric acid has been regarded as probably the limit to be expected, even in special cases, from the minerals containing water most loosely combined, as in the zeolites and others.

It seems almost superfluous to mention, in this connection, the importance of including in the results the so-called hygroscopic moisture in the analysis of minerals. Indeed, upon comparing the results given above (only the last two analyses are referred to for comparison, as the first is too obviously a mixture) with the published analyses of chrysocolla given in the table below (from Rammelberg's "Mineralchemie," 1860, page 551), one is inclined to suspect that possibly considerable "hygroscopic" water was overlooked in some of the latter, or else there is something inherently different in the two classes. It will be noticed that while the amounts of silica are similar, the cupric oxide in No. 2 and No. 3 is about one-fourth less and the amount of water is about one-half as much more than the other analyses show. The loss of No. 2 and No. 3 over sulphuric acid closely approximates two-thirds of the total water present.

			3			
	1	2	*a*	*b*	4	5
SiO_2	37·25	40·00	35·00	36·54	35·14	32·55
CuO	45·17	42·60	39·90	40·00	43 07	42·32
Fe_2O_3	....	1·40	3·00	1·00	1·09*	1·63
CaO	....	....	....	....	....	1·76
MgO	....	....	....	....	....	1·06
H_2O	17·00	16·00	21·00	20·20	20·36	20·68
Gangue ..	....	....	1·10	2·10	....	....
	99·42	100·00	100·00	99·84	99·66	100·00

* With Al_2O_3, CaO, K_2O.

As to any formula being deduced from the analyses given, the case seems hopeless without resorting to assumptions that are, to say the least, questionable.

The duties of a commercial laboratory afford scant opportunity for purely scientific investigation, however interesting, and it was only after many interruptions that the above work was accomplished, but it is offered as food for speculation and a stimulus for future investigation with the hope that some one with more time and ability may be able to grasp the significance of this remarkable behavior.

Laboratory of the St. Louis Sampling and Testing Works,
St. Louis, Missouri.

ART. V.—*An Inquiry into the Cause of the Nebulosity around Nova Persei;* by FRANK W. VERY.

THE processes by which the nebular illumination around the great nova of 1901 has been produced may conceivably be explained under some one of the following heads:

First hypothesis: The nebular radiation is emitted from myriads of small gaseous masses, either heated or electrified, which have been evolved in the collision of meteorites, belonging to antagonistic and mutually interpenetrating meteor swarms whose motions through space, under the action of gravitation, has brought them together.

Second hypothesis: Radiation from the nova, perhaps of Hertzian waves, perhaps of ordinary luminous vibrations, or possibly of some especially potent ultra-violet rays, but at any rate proceeding in radial lines from the source, has been received upon quiescent matter already existing in the surrounding space, and has generated in this matter some chemical or physical process attended by radiation affecting a photographic plate, or else the material of space, by simple diffuse reflection, has turned the path of the original rays earthwards without altering their quality.

Third hypothesis: Powerful explosions from the nova, and the emission of great volumes of excessively hot gases, have been accompanied by violent electric disturbances which have produced extensive discharges of ions under magnetic control, moving with velocities possibly as great as those of electromagnetic waves, but along magnetic lines of force, instead of radially. The luminous phenomena of the nebula may be conceived either as due to phosphorescence of quiescent matter under impact of the flying ions, or as emanating from the ions themselves.

Either of these three heads may be subdivided into subordinate modes of origin, only a few of which are indicated.* Since any one of these processes may conceivably produce a luminous effect analogous to the nebula, we must decide between the proposed explanations by considering the objec-

* Dr. Max Wolf (Astronomische Nachrichten, No. 3752, Bd. 157, 144, Dec., 1901) suggests for the origin of the nebula the progression of an explosive wave in detonating gas ("Knallgas"), a term which is used to denote an explosive mixture of hydrogen and oxygen, such as is produced in our laboratories by the electrolysis of water. Mr. H. B. Dixon, however, has measured the velocity of the propagation of an explosion in a mixture of these gases, obtaining 2819 meters per second, or a quantity which bears no comparison to the nebular velocity (see Rep. British Assoc. for Adv. Sci., 1885, p. 905). The supposition of an explosion of a mixture of hydrogen and chlorine, which might be started by light from the nova, is open to the same objections as the other radiant hypotheses.

tions which can be urged against them, either from rational considerations, or on the ground of observational data, especially availing ourselves of every scrap of observation which can support either of the hypotheses.

(1) The first explanation, attributing the phenomenon to colliding meteor swarms, has been chiefly advocated by Sir Norman Lockyer. The certain existence of meteor swarms in free space, and the partial agreement between the spectra of some meteorites and nebulæ, are strong points in favor of the general theory. The fatal objections to the explanation in the present case are: (*a*) That the expansion of the nebula has proceeded at too rapid a rate. Let us suppose that two spherical swarms of equal diameter and equal velocities of 100 kilometers per second, are traveling in opposite directions along a common diameter, and that the circle of the intersecting surfaces moves outward with the velocity of light, which it must do if the nebular expansion has been produced in this way. In one year each body will have moved through 3156×10^6 km., and the line of intersection will have expanded through nine and one-half billion kilometers (English numeration). Allowing that the nova is in the center of its sphere, and measuring from this center, the angular aperture of the lenticular volume bounded by the intersecting swarm-surfaces, after one year, is less than 3°, and if the nova's parallax is $0''{\cdot}05$, the swarm will stretch two-thirds of the way to the sun! Even the broad celestial spaces are not wide enough to contain such monsters. (*b*) The fading of the nebula has been too rapid, for there is no reason to suppose that the meteoric particles are confined to a thin superficial shell and that the space within is relatively vacant. (*c*) As it would take over 100,000 years for the motion to pass from the circumference to the center of the sphere, any connection between the actual nova and the nebula would be impossible on this hypothesis. I showed in a previous paper* that the outburst of the nova itself cannot be due to colliding meteor swarms. It is, if anything, more completely demonstrable that the nebula has no such origin.

Sir Norman Lockyer explains the nebula around *Nova Persei* as "a nebula [previously too faint to be detected] invaded, not by one, but by many swarms [of meteors], under such conditions that the collision effects vary very greatly in intensity. . . . The most violent one . . . constitutes *Nova Persei*. The least violent ones occurring in other parts of the disturbed nebula, almost immeasurably removed, i. e., more than 700 solar distances away, we only learn of from the recent photographs."† The distances are here greatly underesti-

* This Journal (4), xiii, 114. † Nature, lxv, 134, Dec. 12, 1901.

mated, in fact the nebular velocities seem to be confounded with those spectroscopically observed. I have shown elsewhere* that the gaseous envelopes about the nova, whose existence we must infer from the spectroscopic observations, belong to an entirely different order of magnitude from the nebulous forms which have been discovered by photography. The latter probably extend to 100,000 solar distances. The general combination of the nebular details into nearly circular rings which have expanded in a continuous manner, requires that the aggregate of the swarms postulated shall be spherical.

(2) There are various hypotheses assigning the nebular phenomenon to the action of radiation from the nova on diffused quiescent matter already existing in surrounding space, for example: (*a*) The hypothesis of electro-magnetic waves, emitted by the nova at its maximum development, exciting luminosity in masses of rarified gas, after the manner of Tesla's disconnected tubes. (*b*) The hypothesis of dissociation of a compound gas by ultra-violet radiation proceeding from the nova at its maximum intensity, and the subsequent production of light by the recombination of the atoms. (*c*) The hypothesis that luminous radiation from the nova has been reflected by finely divided matter.

The following objections apply to all three of these hypotheses: 1. The duplicity, or possible triplicity of the nebulous ring, and the double ratio of the radii of the two principal rings, are not explained. 2. The expansion of the concentric rings should be uniform, since any supposition of cylindroid or conoidal nebulosities, directed earthwards, is improbable. But instead of uniform expansion in a radial direction, there has been retardation in the movement after a certain time. The deviation from radial direction of movement in special forms does not enter into the argument, which concerns rather the figure produced by the combination of details into an annulus whose outer boundary may be taken to limit the region through which a special process has progressed. 3. The deviation of both rings from the circular to an elliptical shape, and to the same extent, is not easy to explain by radiant hypotheses. Mr. Arthur R. Hinks, of Cambridge Observatory, England,† suggests reflection of light from inclined circular rings of nebulous material, concentric with the star; but this requires several years for the completion of each ellipse, whereas the ellipses are already very nearly complete through arcs far in advance of the arrow heads which are supposed to be describing these figures. 4. Finally, the reflection hypothesis in any

* Astronomische Nachrichten, No. 3771, clviii, 33, Feb., 1902.
† Astrophysical Journal, xvi, 198, 1902.

of its forms, whether as developed by Kapteyn* or by Seeliger† or by Hinks, presupposes an albedo which is quite impossible in nebulous material as it actually exists in extreme rarefaction. Professor H. H. Turner‡ has given the following rough but simple calculation in regard to Kapteyn's hypothesis: "Light takes 8 min. to reach the moon from the sun, 8 months to reach the nebula from *Nova Persei*. Taking the original flare up to be 5000 times the brightness of our sun, the illumination of the nebula should be to that of the moon as 5000 to $(30\times24\times60)^2$. The moon could be photographed with Mr. Ritchey's instrument in (say) $0^m{\cdot}003$. Hence the nebula, if of the same albedo as the moon [could be photographed] in $0^m{\cdot}003\times(30\times24\times60)^2\div5000 = 20$ min. say. The actual exposures required," says Professor Turner, "thus seem reasonable on Kapteyn's hypothesis." Let us see what this "reasonable" conclusion implies. It will be noted that in forming his equation, Professor Turner has introduced the proviso of equal albedo in nebula and moon. The assumption remains in the final conclusion, and how far it is from the truth may be seen from the following considerations: In 1895, I measured the light from a small area of the moon in total eclipse,§ photometrically, and found it to be four one-thousand-millionths of the light from a corresponding fraction of the full moon. My range of vision embraces lights which are in the ratio of 1 to 1,000,000,000,000,000. Hence I could certainly see a small luminous surface considerably fainter than the fraction (less than 1 per cent) of the eclipsed moon, and as no one has been able to see the nebula, I conclude that its light must be less than one one-thousand-millionth of that from an equal area of the full moon. Professor Turner's calculation demands equal albedo, that is, equal intrinsic brightness from the same angular area in the two cases. We are not concerned with the albedo of the individual reflecting particles in the nebula. This may be exactly the same as the moon's albedo, but that is not the question. The albedo of the nebula is the effective albedo of a surface, apparently continuous, but in reality undoubtedly composed of excessively minute particles separated by large vacant spaces. With the actual effective nebulous albedo of 10^{-9} (moon = unity), we see from Professor Turner's own figures that the conclusion which he draws is not warranted, and that no reflection from nebulous material at the vast distance of these nebulous forms from the central illuminating body can affect the photographic plate,

* Astronomische Nachrichten, No. 3756, clvii, 201, Dec., 1901.
† Astrophysical Journal, xvi, 187, 1902.
‡ The Observatory, Feb., 1902.
§ "Photometry of a Lunar Eclipse," Astrophysical Journal, ii, 293, 1895.

even though the exposure were to be prolonged many thousand fold.

(3) The supposition that the observed motions are actually those of some form of matter, either itself luminous, or producing luminosity in widely distributed material with which the moving substances react, demands so large an expenditure of force in sustaining the prolonged movement to enormous distances, that some hesitation in adopting it is pardonable. Yet, considering the stupendous scale of operations in the nova, the objections on this score do not seem insuperable. Comet's tails have been seen to develop through millious of miles in a few hours,* perhaps by electric repulsion, perhaps by the pressure of light on small masses, but at any rate without demanding greater force than the sun is competent to produce. High velocities have been measured in vacuum tubes for the cathode rays, and yet higher ones for the luminous column from the positive pole, even approaching, if not equaling that of light. These facts at once suggest a movement of Thomsonian corpuscles, or negative ions, under a magneto-electric impulse, as a solution of the problem.

Professor C. D. Perrine, however, has urged what appear to him to be further objections to the hypothesis of a real translation of matter. He says:† "The motions observed are not radial. Nearly all of them have large tangential components. It is difficult to account for these tangential components. A consideration of the conditions probably existing in the nebula, upon the assumption of an actual translation of matter, would lead us to expect a very rapid loss of light. The inner ring has decreased in brightness, and some of its features have become too faint to record themselves on the photographs. Several masses, all in the outer ring, have been recorded only on the later photographs, and have grown both in brightness and size, a condition difficult to explain on the above hypothesis. It is perhaps not inconceivable that the two rings represent different phenomena." If these difficulties urged by Professor Perrine can be removed, nay more, if the facts con-

* Miss Agnes M. Clerke, in her "History of Astronomy during the Nineteenth Century" (4th ed., p. 100), says of the comet of 1811, that Olbers "calculated that the particles expelled from the head traveled to the remote extremity of the tail in eleven minutes, indicating by this enormous rapidity of movement (comparable to that of the transmission of light) the action of a force much more powerful than the opposing one of gravity." By reference to Olbers' original communication in Zach's Monatliche Correspondenz (xxv, pp. 3–22, 1812) it will be seen that the extreme length of the tail of this comet, on October 13, 1811, was taken at 0·6391 astronomical units, or about 96,000,000 kilometers; and the time consumed by the vapors in attaining this distance, computed according to Newton's method, was stated to be *eleven days*, instead of eleven minutes.

† Astrophysical Journal, xvi, 260, 1902.

sidered to be objections to a theory of real motion can be shown to be demanded by a special form of the theory, they constitute a strong argument in favor of this explanation. I believe that such a modified explanation is indicated.

The difficulties urged by Perrine in regard to the sudden appearance and brightening of local spots on the outer ring, and the tangential motion which prevails in many features, appear to him contrary to what should be expected if the phenomenon is due to actual motion. Evidently the only actual motion considered is a radial one. These difficulties which form the most serious objection to such theories of actual motion as have been hitherto published, become, on the contrary, a strong argument in favor of a different theory of real movement.

(4) The theory which I would propose is that of the actual movement of diamagnetic ions under the control of magneto-electric impulses emanating from the star and following the lines of magnetic force. We may compare such a stream of moving ions to the beam of light from a parabolic mirror. The rays are directed and do not at once expand to fill the entire sphere. Diamagnetic ions may be expected to follow lines of magnetic force to regions of least potential in the magnetic equatorial plane, and with only slight expansion of the tubes of force through a limited range of the magnetic sphere. Hence the luminosity, as in the distinct phenomenon of a comet's tail, may extend to a great distance before becoming too faint for observation, although of course the light must eventually fade, unless perpetually renewed. This seems to answer the objection on account of the long continuance of the phenomenon.

In the next place, if the structure observed in the nebula is to be compared with that of a magnetic phantom, a strong tangential component must enter into lines emanating from the nova after these have extended to a certain distance. The magnetic phantom, whether exhibited by iron filings or by dust of bismuth, extends in sweeping curves from pole to pole of the magnet—the only difference being that magnetic particles move towards the poles, and diamagnetic away from them, but that both follow the lines of force. The observed trajectories of nebulous material around the nova are in fair, perhaps I should say in nearly perfect, agreement with the projection of a system of lines of magnetic force.

If the brightening or sudden appearance of new bright spots on the outer ring can also be explained on this hypothesis, I think it must be admitted that the facts decidedly favor, if they do not demonstrate, the proposed explanation.

Two cases may be distinguished: *(a)* The light is produced

by phosphorescence of dark matter, previously existing in the surrounding space, and made luminous by colliding ions. *(b)* The moving ions are themselves luminous.

On either hypothesis, the luminous shape is a species of magnetic phantom, where only those portions of the general magnetic figure are visible which happen to be infilled with matter capable of becoming luminous under the given conditions.

Two distinct processes can be inferred from the succession of phenomena exhibited by *Nova Persei*. First, there were violent eruptions of hydrogen, helium, etc., with velocities up to 2000 km. per sec., and the formation of concentric shells of glowing gas, reaching distances comparable with those of the planetary orbits; and, second, there was a profound electrical disturbance accompanying this turmoil of the elements, producing a complex and excessively attenuated appendage, thrown off with velocities possibly 150 times as great as those of the gaseous eruptions, and reaching far out into stellar space. It is this second appendage with which we are now concerned. We see this object on the photographic plate in projection, and must infer its shape from such details as are visible. A strong condensation on the S.S.W. side reminds one of the jets from a cometary nucleus on the side towards the sun, and to this extent favors some such theory as that of Professor T. C. Chamberlin, who has suggested* the tidal disruption of a star upon the near approach of a massive dark body. The condensation in question, called *m* by Ritchey and D by Perrine, bears an even stronger resemblance to the polar coronal filaments of the eclipsed sun, which curve away on either side of the coronal axis, but with the difference that it appears at only one pole.

Let us assume that there has been an ionic discharge following the lines of magnetic force around a highly magnetized sphere. The general form of an envelope, consisting of a series of such discharges, will be that of an oblate spheroid with polar depressions (i. e., a species of lemniscoid); and if the nebula about *Nova Persei* is to be thus interpreted, its southern pole is directed towards us, the axis forming an angle of 40° with the line of sight.

Consider a magnetic line of force lying in a plane including the line of sight from the star to the earth (whose direction is indicated by the arrow from the nova *o* in fig. 1). Particles emitted from *o* and passing to *m* will be moving almost end-on, and the line of sight will encounter many such particles. The prominence *m* is therefore brilliant and changes its position slowly. Particles moving along the curve to *p* reach a part of

* Astrophysical Journal, xiv, 17, 1901.

their trajectory where they begin to recede from us with increasing velocity. If the actual velocity is that of light, the component of motion in the line of sight will soon reach a high value—let us say 100,000 km. per sec.—when, even if the original ionic radiation were rich in violet and ultra-violet light, the waves of ether must be so lengthened by the motion of recession that they no longer impress the photographic plate. Consequently, at this radial distance from the star, and in like manner on the opposite side at t, the nebula fades out; but at nearly the same radial distance, particles which have passed undetected on account of their recession along lines from the star's north pole, reach, at t' and p', positions where the motion of recession changes to one of approach. Violet light begins to emanate from these regions. Soon the motion

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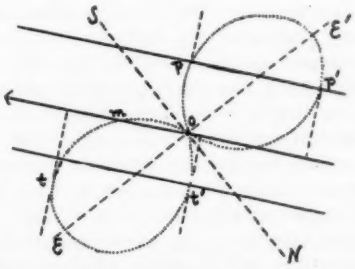

of approach becomes so vigorous that even red or infra-red rays, if they exist, will have their wave-lengths so shortened that they can be photographed. On the supposition that the nebula is a gigantic corona with symmetrical sheaves of filaments around both poles, diverging under angles of something over 60°—one capable of being photographed, the other not—the puzzling phenomena of appearance and disappearance at the outer ring are explained. They are demanded by the theory, instead of being anomalies. The spectroscope alone can decide whether these hypothetical changes of wave-length are real; and as yet this evidence is wanting. If the spectroscope should decide against the change, the supposition of direct ionic luminosity would have to be given up, but not necessarily the ionic theory, since there remains the hypothesis of phosphorescence of quiescent matter under ionic impact.

Perrine's observation of March 29, 1901, indicates the existence, at that date, of two nebulous rings, with radii in the ratio of 1 : 2, and an arc on the N.E. side, which perhaps is the sole record of a third and wider ring. The three radii having approximately the ratio 1 : 2 : 4, may correspond to ions

having masses in the ratio of 4 : 2 : 1, and, if so, bear witness to the existence of at least three sorts of ions out of which, in varying proportions, we may conceive the atoms to be made.

An alternative hypothesis assumes that there are as many kinds of ions as of atoms, and that the difference between a corpuscle and an atom of the same substance is principally one of size. If so, since the atomic weights of hydrogen and helium are as 1 to 4, if the masses of their corpuscles have the same ratio, the outer arc might be composed of hydrogen corpuscles, the inner ring of helium corpuscles, and the central member of the series, that is, what we call the "outer ring," would consist of corpuscles belonging to an unknown substance with atomic weight of two. A single good spectroscopic observation, such as might possibly be obtained with an objective prism of large size, would be of inestimable value in deciding this and other questions raised by this extraordinary object, whose like may not be seen again for many years.*

A selection between these hypotheses will be a matter of opinion. Seeing that the chemical elements exhibit many properties analogous to those of homologous series in hydrocarbons, I am inclined to favor the supposition that the atoms are formed by various arrangements of numerous ions of perhaps only three species. Even when their motions are confined and limited in the ionic aggregate (the atom), three fundamental sorts of ionic motions are distinguishable in principal, first subordinate, and second subordinate series of spectral lines, whose pressure shifts, according to Dr. W. J. Humphreys,† are in the ratio 1 : 2 : 4. The same sequence appears again in

* Note added April, 1903.—Since this paper was read at the annual meeting of the Astronomical and Astrophysical Society of America, in Washington, December, 1902, Professor Perrine has published the following measurement, made with a slit-spectrograph of special construction, provided with a quartz prism and quartz lenses: "The slit of the spectrograph was placed across the brightest portion of condensation D. The resulting negative showed a very faint spectrum, which, after careful consideration and some experiments was deemed to be that of the nebulosity. So far as can be told from such small dispersion and intensity, the spectrum is continuous, with the greater portion of the light condensed in a band between $H\beta$ and $H\gamma$. This band is strongest just above $H\beta$ and from this point fades gradually until it is entirely lost in the H and K calcium region. Beyond this point, up to the ultra-violet region, there is a very slight increase of strength again. It is suspected that in one or two cases there may be traces of bright lines, but the whole spectrum is so faint as to preclude any definite deduction on this point. The above observation shows that the spectrum of this mass of nebulosity is not the ordinary bright-line spectrum of the nebulæ." (Publications of the Astronomical Society of the Pacific, XV, No. 88, p. 26, 1903.) This observation is not inconsistent with the supposition that a spectrum, normally composed of bright lines, has been extended and diffused by excessive motion of the radiating particles through a considerable range of velocities, according to Doppler's principle, until the resulting spectrum is one of ill-defined, superposed, hazy bands.

† Astrophysical Journal, vi, 219, 1897.

the differences between the vibration-numbers of the components of the triplets in the spectra of many of the elements, for example, ratio of intervals: zinc 2·07, magnesium (b line) 2·03, oxygen 1·78 to 2·0, calcium 2·02, etc.

An examination of the rate of expansion of the nebula shows that, since the hundredth day from the outburst of the nova, there has been a retardation, and probably an increasing retardation, in the motion of the nebulous rings. I assume that the nebula consists, in a general way, of two or more lemniscoidal

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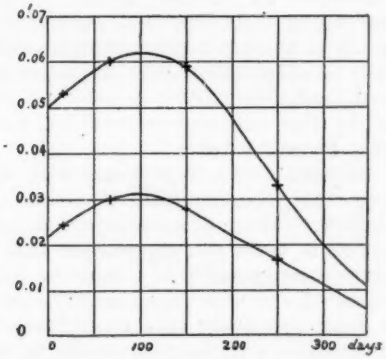


shells involving minor details of structure which find their limit in the elliptical projection of equatorial circles of the lemniscoids. Since the minor details are of vague shape and difficult to locate with precision, I prefer to estimate the positions of the elliptical rings, and taking the mean of major and minor semi-axes as varying with the successive loci of the motion which traces the lemniscoidal figure, I obtain for the rate of nebular expansion the values contained in the following table:

	Time interval.	Mean radius.	Expansion—Mean daily rate.
	0–36 days	1″·85	0″·0514
Outer	36–100 "	5 ·7	0 ·0602
shell	100–200 "	11 ·6	0 ·0590
	200–300 "	14 ·9	0 ·0330
	0–36 "	0 ·88	0 ·0244
Inner	36–100 "	2 ·8	0 ·0300
shell	100–200 "	5 ·7	0 ·0280
	200–300 "	7 ·4	0 ·0170

The curves of the rates of expansion (fig. 2) differ totally from that of matter moving outward under the retardation of the attraction of a central mass (namely, velocity diminishing with the inverse square root of the distance); but the motion is in

agreement with that to be expected under the influence of gravity and magnetic repulsion combined, and is thus a strong argument in favor of the theory.

Assuming the radius of the nova to be 10,000,000 km., I find the magnetic repulsion upon the ions at the surface of the star must be about 100,000 times as great as the attraction exerted upon them by the star's mass. At a distance (for the outer ring) of about a billion kilometers, however, gravitation becomes the more powerful, and the velocity of recession begins to diminish. The distance of course depends upon the dimensions of the excessively minute corpuscles.

In order to discover whether the forces required to communicate the observed motion are within the limits of possibility, and are able not only to separate and expel but also to guide the ions, I have taken the dimensions given for the corpuscles by Professor J. J. Thomson, and have combined them with my computation of the mass of the nova.* I find that the computed magnetic repulsion (in excess of gravity) could generate a velocity of nearly 100,000 km. per sec. in the first second, if it were able to exert its full power. Hence it does not seem improbable that velocities as great as this, or even three times as great (i. e., having the velocity of light) could be started by electric oscillatory discharges in the huge masses of intensely heated gases erupted from the nova, ionizing them, and preparing material for dissipation and control by the powerful magneto-electric impulses started at the same time.

I suppose the corpuscles or negative ions to be ethereal vortices, and consequently must make the further assumption that they are diamagnetic, in order to account for their being repelled magnetically.

At this point it is possible to descend from the sky to the earth. A laboratory experiment by Goldstein,† which has never been fully explained, furnishes a connecting link in favor of my last assumption. This experimenter subjected a vacuum-tube in which diamagnetic sodium and magnetic nitrogen glowed together under the electric discharge, to the action of a powerful magnetic field, with the result that only the nitrogen glowed, the diamagnetic substance having been entirely cleared away by repulsion. Free diamagnetic substances must tend to accumulate in regions of least magnetic potential, and the diamagnetic hydrogen of the gaseous nebulae possibly maps out such regions.

I will now allude very briefly to the difficulties encountered by the hypothesis. The attraction or repulsion on a magnetic body is a differential one, and in a uniform field increases with

* Astronomische Nachrichten, No. 3771, clviii, 33, 1902.
† Wied. Ann., xii, 261, 1881.

the distance between the poles of the body. The ions are so minute that the differential repulsion on opposite poles of a corpuscle is very small. Morever, if an ion consists of a circulation of electricity, everywhere at right angles to a circular axis, the corpuscle has no free magnetic poles. It is conceivable that an instantaneous variation in the magnetic field may produce within a limited space a gradient of magnetic force which is steep relatively to the dimensions of an ion, and that the corpuscle is carried along at the rate of motion of the magnetic impulse. Unless there is some such process, it is difficult to find a sufficient cause for the deviation of the motion from a radial direction by a magnetic field as feeble as that at the extreme nebular distances. Something remains to be discovered in regard to the way in which magnetic forces of considerable strength are exhibited far from their sources. The volcanic explosion of Mt. Pelée produced an instantaneous magnetic impulse recognizable all over the earth. Rapid changes in large sun-spots are often accompanied by magnetic storms upon the earth, especially if the earth is near a solar radius through the spot, or the tangent plane at the spot's position. A continuous outpouring of magnetic energy in these cases, and to the immensely greater distances of the *Nova Persei* nebula, would dissipate energy at a startling rate; but a series of instantaneous impulses, separated by relatively large intervals of time, while entirely competent to guide the ionic movements, would also economize energy. Besides this, there is a further economy in the magneto-electric impulse which is not shared by the electromagnetic wave, for the former travels along the magnetic lines of force from pole to pole, and is part of a regenerative system, while the electromagnetic waves pass away in ever expanding spheres and are dissipated. The ionic hypothesis of the origin of the nebula is attended by difficulties, but at least it offers the possibility of a complete explanation.

In conclusion, I think that we may summarize the evidence in regard to the cause of the nebulosity around *Nova Persei* as follows:

Lockyer's hypothesis does not fit the facts. The first two radiation hypotheses are ruled out by the continued visibility of the rings in spite of the gradual cessation of motion. The reflection hypothesis of Kapteyn and Seeliger and its modification by Hinks are further discredited by the impossibility of an adequate albedo in a widely dispersed or nebulous material. Of the two ionic hypotheses, that of luminous diamagnetic corpuscles under magnetic control, and moving with velocities of the same order as that of light, is favored by the appearances and disappearances at the outer ring, but only spectroscopic observation can decide between them authoritatively.

Arcturus, Virginia.

ART. VI. — *The Heat of a Change in Connection with Changes in Dielectric Constants and in Volumes;* by C. L. SPEYERS.

WHEN carbon and oxygen react to form carbon dioxide many of us say that chemical energy brings this about; that carbon and oxygen containing more chemical energy than the quantity of carbon dioxide produced, the difference escapes as heat and light. But when asked to define chemical energy we become extremely perplexed. We can measure heat energy as such in water units but we cannot measure chemical energy *as such* in any units. We can measure heat energy as such by the increase in volume produced by it, but we do not know of any effect by which we can measure chemical energy *as such.* Invariably do these attempts result in producing heat energy, or light energy, or electric energy, or mechanical energy, or some other energy. But because we do not find these energies previously in the reacting system, we say they come from the chemical energy, which must have been previously in the system. How account otherwise for the energy evolved?

That is, many of us say this, not all of us. Yet all of us agree that water does not contain chemical energy although it gives out heat and changes into ice when placed in an atmosphere below 0°. We all of us agree to this because we agree to call this change into ice a physical change and not a chemical one. No other real reason. On careful investigation and thought we come to the conclusion that the term "chemical" is one for convenience only, that we cannot distinguish chemical changes from physical ones by any definition that can be experimentally sustained at all points. So if we wish to express things as they are, all we can say is that the term chemical energy is an abbreviation for the statement that some energy is involved in chemical change, *but not that there is such an energy as chemical energy.* Abbreviations are very good and necessary, but unless extremely simple and clear, their proper meaning is likely to be forgotten, and this is what has happened with the term chemical energy. It has come to mean a real thing in the minds of writers. A real thing in an elementary text-book* as well as in the last work by Ostwald, a philosophic work too.† Still Ostwald writes in another place‡ "Jeder, der die Beseitigung einer unhaltbar gewordenen allgemeinen Auffassung und ihren Ersatz durch eine neue sich

* Remsen; Inorganic Chemistry, p. 38 (1889).
† Vorlesungen u. Naturphilosophie, p. 232 (1901).
‡ Ib., p. 166.

zur Lebensaufgabe gemacht hat, muss an irgend einer Stelle seiner Vergangenheit den Tribut zahlen."

The barrenness of the notion of chemical energy shows how useless to seek an explanation of chemical action inside the reacting system. How very productive was Faraday's treatment of electricity and magnetism! Outside the charged sphere, the wire, and the magnet, are the energies.

Just so in chemical reactions, let us say, for example, those involving heat, outside the material part of the system is where we are to find the source of the heat.

Consider an infinite uniform electric field whose dielectric constant is K_0, whose electric intensity is E_0, and whose dielectric displacement is D_0. Then the energy W_0 in a volume v_0 is

$$W_0 = \tfrac{1}{2} E_0 D_0 v_0$$

or, since in a uniform field

$$D_0 = \frac{K_0 E_0}{4\pi},$$

we have

$$W_0 = \frac{K_0 E_0^2}{8\pi} v_0. \qquad (1)$$

Now introduce into the infinite field a sphere of radius b and of volume v_1 and whose dielectric constant is K_1. Since the field is infinite, we consider that no change is made in the total energy of the field outside the sphere, for there is nothing to maintain a change in the intensity of the field if it is not directed, and if it is directed any change produced on one side of the sphere is balanced by an equal opposite change on the other side. Inside the sphere, the electric force is changed to E_1* such that

$$E_1 = \frac{3K_0 E_0}{K_1 + 2K_0}, \qquad (2)$$

the moment M of the imaginary doublet representing the sphere being

$$M = \frac{E_0(K_1 - K_0)}{K_1 + 2K_0} b^3.$$

Substituting 2 in 1, we have for the electric energy W_1 in the sphere

$$W_1 = \frac{9K_0^2 E_0^2}{8\pi(K_1 + 2K_0)^2} v_1. \qquad (3)$$

* Elements of Elect. and Mag., J. J. Thomson, chap. v. (1895).

We shall call the quantities represented by 1 and 3, the *dielectric energies.*

The change in dielectric energy when the sphere is placed in the field is

$$W_1 - W_0 = \frac{K_0 E_0^2}{8\pi}\left(\frac{9K_0^2}{(K_1+2K_0)^2}-1\right)v_1.$$

For a second sphere of dielectric constant K_2 and volume v_2 we have

$$W_2 - W_0 = \frac{K_0 E_0^2}{8\pi}\left(\frac{9K_0^2}{(K_2+2K_0)^2}-1\right)v_2.$$

Consequently the dielectric energy involved in changing the first sphere into the second, if we put $K_0 = 1$, is

$$W_2 - W_1 = \frac{E_0^2}{8\pi}\left[\left(\frac{9}{(K_2+2)^2}-1\right)v_2 - \left(\frac{9}{(K_1+2)^2}-1\right)v_1\right]. \qquad (4)$$

Now imagine that we are living in surroundings corresponding to an electric field and that the energy in the space occupied by a particular body is measured by 3. Then as we produce one set of bodies from another set we can expect such change in the energy of the system as is represented by 4, in which the indices refer to the two sets of bodies respectively. This change should be measured by a corresponding quantity of some other form of energy rejected by the changing system or absorbed by it; for instance, measured by the heat of the change. Whether the change from state 1 into state 2 causes a rejection or absorption of heat is not predicted; the only assumption made is that the dielectric constant measures the effect the body has upon the energy of the field according to the laws of electric action, when placed in that field.

Equation 4 was deduced for spheres, but since such very slight changes are produced in the properties of a system by moderate subdivision, we claim the same relation for all shapes.

Let us apply 4 to vaporization, for there are enough data in Landolt and Börnstein's Tabellen and elsewhere for three liquids, sulphur dioxide, ammonia, and water. In this case $W_2 - W_1 = Q$ and if $8\pi/E_0^2 = A$, we have

$$\left(1-\frac{9}{(K_2+2)^2}\right)v_2 - \left(1-\frac{9}{(K_1+2)^2}\right)v_1 = AQ \qquad (5)$$

where v_2 is the volume in c.c. of saturated vapor produced from v_1 in c.c. of liquid and K_2 and K_1 are the respective dielectric constants of vapor and liquid.

It will be convenient to put $v_1 = 1^{cc}$, in which case Q is the heat of vaporization of 1^{cc} of liquid.

The data for carbon dioxide cannot be used without extreme extrapolation.

In the following table, t^0 is the temperature of vaporization, p is the pressure in atmospheres, d_1 is the weight in grams of 1^{cc} of liquid at t^0 and under p pressure, d_2 is the weight in grams of 1^{cc} of saturated vapor at t^0, v_2 is the volume of saturated vapor at t_0 produced from 1^{cc} of liquid at t^0, K_2 is the dielectric constant of the saturated vapor and K_1 that of the liquid, both at t^0 and under p pressure.

	t^0	p	d_1	d_2	v_2	K_2	K_1	Q	A10^4
SO_2	23°	3·60[1]	1·37[1]	0·0107[1]	128	1·031[1]	14·8[3]	114[3]	140
NH_3	18°	7·89[1]	0·612[1]	0·0055[5]	111	1·058[4]	20[6]	181[2]	175
H_2O	140°	3·57[1]	0·95[7]	0·0020[7]	475	1·027[4]	40	481[7]	154

[1] Tabellen; L. and B.
[2] Tabellen; by interpolation and computing for 1^{cc}.
[3] Linde; Wied. Ann. lvi, 563 (1895).
[4] Bädeker; Zeitsch. phys. Chem. xxxvi, 305 (1901). By interpolation and calculating to p by Boltzmann's rule.
[5] Calculated by Boyle-Avogadro law.
[6] Franklin and Kraus; Am. Chem. Journ. xxi, 14 (1899).
[7] From Tabellen dp/dT between 135° to 145° = $77·2^{mm}$ Hg. Taking 0·95 as the density of liquid water at 140°, we have $v_2 = 475$ and

$$Q = \frac{413(475-1)7.72 \cdot 13.6}{42750} = 481 \text{ cals.}$$

Substituting these values in 5, we get for A the values given in the last column. They were considered close enough to warrant further research, particularly as the uncertainties in the tabulated data are unknown and a slight change in K makes a large difference in A. For instance, putting 1·030 instead of 1·027 for the dielectric constant of water vapor gives 0·0173 for A instead of 0·0154.

In continuation of this line of work, a simple investigation seemed to be one into the heats of solution. Carbon compounds in carbon solvents were chosen to avoid complications which might arise from the presence of a metallic component and because a considerable quantity of necessary data had already been accumulated.

The dielectric constants were measured by the method of Drude.* It seemed advantageous to put a layer of sheet rubber on the secondary coil of the Tesla transformer and to wind the three turns of the primary on that instead of on a

* Wied. Ann., lxi, 466 (1897). Drude's Ann., viii, 336 (1902).

wood cylinder. Perhaps in view of the recent research by Drude* that was not a good plan, but these determinations were finished before this last work of Drude came to my notice. The use of mercury for the inside coating of the Leyden jar was a great convenience, for then the capacity could be adjusted with great nicety. The vacuum tube for the detector was on the Nernst† plan.

The length of the induced wave in air was $71{\cdot}5^{cm}$ and this was the second wave from the exciter, not the one taking in the brass tubes. The stationary bridge was always grounded.

The acetone for standardizing came from Eimer and Amend. No mark. It was changed into the acid sodium sulphite compound and this decomposed by chemically pure normal sodium carbonate. The liquid was dried over calcium chloride for twenty-four hours and distilled from fresh calcium chloride. Its boiling point was 56·8° to 57·8° cor., barometer = 763^{mm} at 22°.

The benzene for standardizing came from Kahlbaum. Marked "Crystall." Tested for thiophene but none found. Not otherwise examined or purified since an accuracy greater than 5 per cent. could not be obtained when the dielectric constants were so low as that of benzene.

The average room temperature was 22°, ranging from 19° to 25°.

Two sets of three double observations each of the wave lengths were measured, the two sets being made at different times, though with the same solutions. The mean of these two sets was subtracted from the zero point, that is, from the position of the slide when the condenser was replaced by a metallic bridge, and the dielectric constant read off from the calibration curve. The zero point was determined every day and was the average of three observations. Two independent series of observations were made for the calibration curve, one at the commencement of the measurements of the dielectric constant and one at the end of all the measurements. These two series were plotted and form the calibration curve. Each series consisted of two sets of three double observations, the two sets being made at different times but with the same solutions. So the curve is the result of 12 observations at each point of plotting. Notwithstanding much care, the curve was not all that could be desired, for at times an observation or a number of them would slip far away from neighboring ones.

The solvents and solutes have already been described in preceding papers. The solutions were made by placing the solutions, saturated at a higher temperature, in running city

* Drude's Ann., ix, 293, 590 (1902). † Wied. Ann., lx, 303 (1897).

water and letting them stand over night. That gave plenty of time for proper separation and the temperature of the running city water was very constant, ranging from 22·0° to 22·8° cor. An ordinary thermostat could not have been used below 30° on account of the hot summer weather, and then would have come the trouble with crystallization when the solutions were cooled to the room temperature to go into the condenser.

The dielectric constants for the solid solutes were obtained by melting and letting them solidify in the condenser. When the series of measurements with the solid solutes was finished, the condenser was filled with pure acetone and the dielectric constant measured again. No change in value could be detected, showing no change in the position of the condenser plates.

The conductivity of the solutions was found to be so low that there was no danger of interference from that source. The highest conductivity was that of acetamid in water = 0·0018 coulombs per sec. through 1^{cc} at 1 volt *p. d.*, while the lowest was $< 0{\cdot}0{,}2$ coulombs per sec. through 1^{cc} at 1 volt p. d. and this was a solution in toluene.

The dielectric constants are given in the large table together with their estimated uncertainties. Also the function $1-9/(K+2)^2$ with its "mean uncertainty." This "mean uncertainty" is found by computing the function when the estimated uncertainty is added to K and when it is subtracted from K, which two values will be quite unequally distant from $1-9(K+2)^2$ when K is small, and taking the mean of these differences from the function when the experimentally observed value of K is used. When K is greater than 16, the value of the function is about the same whether the uncertainty in K is added to K or subtracted from it.

The densities of the solutes, solvents, and solutions are needed to find their volumes. The densities of the last two have already been determined,* but not the densities of all the solutes. Landolt and Börnstein quote some data from Schroeder and others, but the trouble which Schroeder had with air bubbles made his results a little questionable and a redetermination of them seemed desirable, while at the same time the necessary new data could be obtained.

The densities were found by weighing in saturated solutions of kerosene or of amyl alcohol, according to the nature of the solid. Kerosene was excellent; only naphthalene, acenaphthene, and phenanthrene were too soluble in it; for these, amyl alcohol was used. The air bubbles with kerosene were insignificant, but with amyl alcohol they were sometimes quite annoying and could not be altogether removed, but those left are not believed to have influenced the second decimal place at

* This Journal, xiv, 293 (1902).

all; the data are to be considered correct in all cases to and including the second decimal place. Boiling the amyl alcohol under reduced pressure diminished the air bubbles somewhat. The best way to remove them seemed to be to roll the specific gravity flame round and round after displacing some of the liquid with the proper quantity of solid. In this way a large number of air bubbles were loosened and rose to the surface, but not all; for after the weighings were completed, another rolling would show a few more air bubbles. In the worst case, those remaining had a volume of perhaps $(2^{mm})^3$, hardly more, so in this worst case the error due to air bubbles fell within the uncertainty due to variation in the temperature of the thermostat.

The solutes were purified carefully as in the earlier investigations.

The process consisted in saturating the kerosene or amyl-alcohol with the solid whose density was to be determined, finding the density of this saturated liquid in a specific flask holding 25^{cc}, and displacing some of the liquid by a known weight of the solid as powder or small crystals. From 4 to 11 grams of solid were used.

The weighings were not reduced to vacuo because the temperature of the thermostat varied through a range of 0·2°.

Two altogether independent determinations were made. The temperature of the thermostat was 22·2°±0·1 uncor. The experiments were simple and need no detailed description.

The data are given in the table below, the mean values being used in the large table further on. L. and B. signify Landolt and Börnstein's Tabellen.

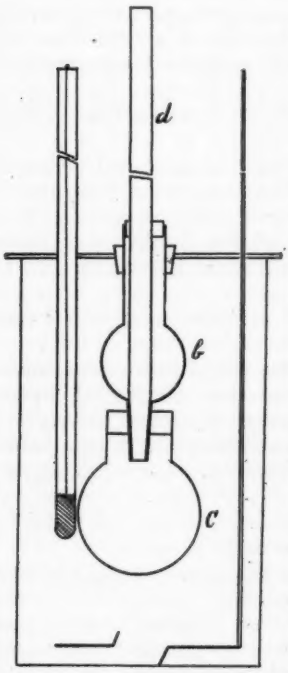
Weight in Grams of 1^{cc}.

Urea	1·322	1·315	Mean	1·318	L. and B.	1·33
Urethane	1·133	1·139	"	1·136		
Chloral hydrate	1·900	1·894	"	1·897	"	1·86
Succinimid ($C_4H_5O_2N$)	1·408	1·406	"	1·407		
Acetamid	1·127*	1·129†	"	1·128	"	1·159
Resorcinol	1·274	1·272	"	1·273	"	1·283
Mannitol	1·486	1·480	"	1·483	"	1·488
Benzamid	1·267	1·275	"	1·271	"	1·341
p-Toluidin	1·122	1·124	"	1·123	"	1·046
Acetanilid	1·204	1·207	"	1·205	"	1·211
Naphthalene	1·169	1·176	"	1·172	"	1·145
Acenaphthene	1·205	1·201	"	1·203‡		
Phenanthrene	1·179	1·181	"	1·180		

* Some crystals contained large bubbles.
† Fused and powdered.
‡ Bubbles = $(2^{mm})^3$.

The benzamid used came from Kahlbaum and had a melting point of 126·5° cor. which did not change on one recrystallization from ethyl alcohol, so the large difference between these values and the one quoted by L. and B. is unexplained. In the case of *p*-toluidin, the difference may be due air bubbles with Schroeder.

The next thing to be determined was the heat of formation of the saturated solution from solute and solvent.



The calorimeter used is figured here. The large glass beaker held 500^{cc} water comfortably. The spherical portion of *c* held 25^{cc}. In this was the solute, small crystals or coarse powder. From 7 to 22 grams of it. The vessel *b* held about 4^{cc} and contained the solvent in such quantity that when run into *c*, a fairly thick paste was formed and there was no reasonable doubt that the solvent became saturated before the end of the experiment. It was run in at the proper time by raising the long ground glass stopper *d*. From 0·7 to 6·7 grams of solvent. The vessel *b* was securely fastened by a cork into the cover of the calorimeter and supported *c* by a watertight rubber stopper. The vessel *c* was weighed with solute in it before submersion in the calorimeter and afterwards when the observation of the thermometer was finished. The increase in weight gave the quantity run in from *b*. The solubilities being known,* the composition of the solution formed could be calculated. The thermometer and platinum stirrer were those used in an earlier investigation into the heat of formation of highly dilute solutions.† The calorimeter stood in a bright tin vessel which in turn stood in another bright tin vessel submerged to the rim in a thermostat at 22·3°±0·1, the space between being packed with cotton.

An experiment was made to see if the large excess of solute

* This Journal, xiv, 293 (1902).

†Journ. Am. Chem. Soc. xviii, 146 (1896).

would absorb enough saturated solution on its surface to affect the temperature. Propyl alcohol saturated with acenaphthene, which dissolves very slightly in it, as liquid was used and acenaphthene as solid. The quantities were 3·1 grms. of saturated solution and 5·6 grms. of acenaphthene. After 5 mins. the mercury had risen 0·001° while the regular rise per minute before running in the liquid was 0·0001°. This lay within the uncertainty of reading and the conclusion was drawn that the surface action was too slight to be noticed.

The thermometer was read by a telescope and under favorable circumstances 0·001° could be estimated, but in general this was not possible and so the thermometer readings are to be considered uncertain to ±0·001°.

The correction for radiation was deduced on the assumption that the change in temperature of a body is proportional to the difference between its temperature and that of its surroundings. Let T be the total change in temperature of the calorimeter from the time of running in the solvent to the time it is saturated, t_1 be the change in temperature at the end of the first minute after running the solvent in, Δt_1 be the average change per minute of the calorimeter for 10 mins. before running in the solvent, and Δt_2 be the average change per minute for 10 mins. after the solvent is saturated. The change T is always a drop, always −. So for the first minute the correction is

$$-\left[\frac{T-t_1}{T}\Delta t_1+\frac{t_1}{T}\Delta t_2\right]$$

and for the second minute

$$-\left[\frac{T-t_2}{T}\Delta t_1+\frac{t_2}{T}\Delta t_2\right]$$

and for the n^{th} minute

$$-\frac{nT\Delta t_1+(t_1+t_2+\ldots.t_n)(\Delta t_2-\Delta t_1)}{T},$$

n being the number of minutes needed for the solvent to get saturated, beginning from the time the solvent was run into c. This was shown by the mercury beginning to rise after its fall or by Δt_2 being less than Δt_1 if Δt_1 was negative. Sometimes the external temperature would change during an experiment in such way that Δt_2 and Δt_1 got opposite signs, and sometimes when T was small $\Delta t_2=\Delta t_1$, and it became very difficult to fix on a proper value for n. In general, n was less than 40 mins., but once it rose to 102 mins. and once fell to 8 mins.

The water equivalent of the calorimeter and fittings contained an uncertainty of less than 0·2 per cent. In calculating the water equivalent of the solution, 0·5 was taken as the specific heat of the solute and that value given in L. and B.'s Tabellen as the specific heat of the solvent, and the sum of these as the specific heat of the solution. The quantity of solution was small in comparison with the 500^{cc} of water and so this introduces an uncertainty of likewise less the 0·2 per cent. of the total water equivalent.

Let q be the total water equivalent, then the heat of solution is $(T\pm0{\cdot}001)\,(q\pm0{\cdot}001q)$. Let n be the number of grammolecules of solute in 100 grammolecules of saturated solution, m the molecular weight of the solute and M that of the solvent, w be the weight of solvent run into c and d the weight of 1^{cc} of solute, that is, its density. Then letting Q refer to 1^{cc} of solute we have

$$(T\pm0{\cdot}001)\,(q\pm0{\cdot}001q)\,\frac{100-(n\pm\Delta n)}{n\pm\Delta n}\,\frac{M}{m}\,\frac{d}{w}=Q\pm\Delta Q.$$

The expressions Δn and ΔQ represent the uncertainties in the respective quantities; Δn, the uncertainty in reading n from curve; ΔQ, the uncertainty due to the uncertainties on the left. These uncertainties on the left were combined to make a maximum effect and a minimum effect and the mean of these two values was taken as Q, the variation of this mean value from either of the extreme values giving ΔQ.

The quantities M, m, w and d were taken without any uncertainty; the molecular weight, because M and m contain about the same elements, and being in the form of a quotient the uncertainties have a small effect upon Q; w and d, because their uncertainties lie in the third decimal place. The atomic weights used are C = 12, H = 1, O = 16, N = 14, Cl = 35·4. The uncertainty in reading from the solubility curve was never more than 0·4 grammolecules and usually not more than 0·2 grammolecules; that is (Δn was never $>0{\cdot}2$ and usually $\Delta n = 0{\cdot}1$).

The heats of solution are given in the large table following.

The densities of solvents and solutions were taken from plots of published data and will be found in the large table with their uncertainties.

In applying equation 5 to the present system, we must remember that the initial state involves two bodies, solvent and solute, while the final state involves only one, the solution. Putting the volume of the solute for convenience equal to 1^{cc}, we have from 4 or from 5

$$\frac{\left(\frac{9}{(K_1''+2)^2}-1\right)v_1''-\left[\left(\frac{9}{(K_0''+2)^2}-1\right)v_0''+\frac{9}{(K_0'''+2)^2}-1\right]}{Q}=A. \quad (6)$$

Here K_1'' is the dielectric constant of the saturated solution and v_1'' is the volume of the saturated solution produced from 1^{cc} of the solute, K_0'' is the dielectric constant of the solvent and v_0'' the volume of the solvent needed to make a saturated solution with 1^{cc} of the solute, K_0''' is the dielectric constant of the solute, Q is the heat of solution in small calories of 1^{cc} of solute in the necessary quantity of solvent to make a saturated solution at t°, the temperature of solution.

These quantities, together with those needed to get them, are given in the following table, in which the additional symbols are used of $_0'''$ for pure solute, of $_0''$ for pure solvent, of $_1''$ for solution :—

$d_0''' =$ density of solute
$d_0'' =$ " solvent
$d_1'' =$ " solution
$n =$ per cent. grammolecules of solute
$N = 100-n$
$w_0'' =$ weight of solvent $= (NM/nm)d_0'''$
$v_0'' =$ volume of solvent $= w_0''/d_0''$
$v_1'' =$ " solution $= (w_0''+d_0''')d_1''$
$f_0''' = 1-9/(K_0'''+2)^2$
$f_0'' = 1-9/(K_0''+2)^2$
$f_1'' = 1-9/(K_1''+2)^2$
$e =$ the numerator of 6.

An absence of a $\pm$ quantity implies a corresponding absence of uncertainty.

	t_0 cor.	d_0'''	d_0''	d_1''	n	w_0''	v_0''	v_1''	K_0'''	K_0''	K_1''	f_0'''	f_0''	f_1''	e	Q	A10^4
H_2O																	
Urea	22·1°	1·32	1·00	1·15	24·5 ±0·1	1·22	1·22	2·21	3·5 ±0·2	77	90 ±5	0·70 ± 0·02	0·999	0·999	0·29 ±0.02	65·3 ±0·9	44·4 ± 3·6
Urethane	21·7°	1·14	"	1·07	35·5 ±0·2	0·416	0·416	1·46	4·0 ±0·2	"	32 ±1	0·75 ± 0·02	"	0·992	0·28 ±0·02	55·9 ±0·7	50·1 ± 4·2
Chloral hyd.	21·8°	1·90	"	1·56	40·8 ±0·2	0·352	0·352	1·44	3·4 ±0·2	"	33·5 ±1	0·69 ± 0·02	"	0·993	0·39 ±0·02	31·3 ±0·4	125 ± 8
Succinimid $C_4H_5O_2N$	22·3°	1·41	"	1·07	5·2 ±0·1	4·65 ±0·09	4·65 ±0·09	5·66 ±0·08	2·9 ±0·2	"	58 ±1	0·62 ± 0·03	"	0·997	0·36 ±0·20	75·9 ±2·5	48·3 ± 27·9
Acetamid	21·7°	1·13	"	1·04	40·7 ±0·1	0·499	0·499	1·57	7·2 ±0·2	"	90 ±5	0·89	"	0·999	0·18	49·5 ±0·5	36·3 ± 0·3
Resorcinol	21·8°	1·27	"	1·13	17·8 ±0·1	0·965	0·965	1·98	3·2 ±0·2	"	47·5 ±1	0·67 ± 0·02	"	0·996	0·34 ±0·02	41·6 ±0·5	82 ± 6
Mannitol	22·0°	1·48	"	1·06	1·8 ±0·1	8·09 ±0·46	8·09 ±0·46	9·03 ±0·43	3·0 ±0·2	"	77 ±2	0·64 ± 0·03	"	0·999	0·30 ±0·92	50·3 ±4·5	76 ± 190
CH_3OH																	
Urea	22·1°	1·32	0·79	0·87	10·4 ±0·2	6·05 ±0·10	7·66 ±0·13	8·46 ±0·10	3·5 ±0·2	31 ±1	44 ±1	0·70 ± 0·02	0·991	0·996	0·14 ±0·25	52 8 ±2·1	28 ± 48
Urethane	21·6°	1·14	"	1·00	55·5 ±0·1	0·327	0·413	1·47	4·0 ±0·2	"	18·0 ±0·5	0·75 ± 0·02	"	0·997	0·28 ±0·02	46·5 ±0·3	60 ± 4
Acetanilid	22·2°	1·20	"	0·88	10·5 ±0·1	2·44 ±0·02	3·08 ±0·02	4·12 ±0·02	3·0 ±0·2	"	37 ±1	0·64 ± 0·03	"	0·994	0·41 ±0·07	36·1 ±0·9	114 ± 22
Naphthalene	22·1°	1·17	"	0·81	1·8 ±0·1	16·02 ±0·92	20·23 ±1·16	21·27 ±1·14	2·7 ±0·2	"	30 ± 1	0·59 ± 0·35	"	0·991	0·43 ±2·63	48·1 ±5·1	145 ± 559
C_2H_5OH																	
Urea	22·0°	1·32	0·79	0·81	4·0 ±0·1	24·30 ±0·63	30·71 ±0·80	31·59 ±0·78	3·5 ±0·2	21·5 ±0·5	25·0 ±0·5	0·70 ± 0·02	0·984	0·988	0·29 ±1·29	62·7 ±5·2	64 ± 211
Urethane	21·6°	1·14	"	0 97	52·0 ±0·1	0·544	0·688	1·73	4·0 ±0·2	"	16·0 ±0·5	0·75 ± 0·02	"	0·972	0·25 ±0·02	48·4 ±0·4	52 ± 4
Chloral hyd.	21·5°	1·90	"	1·39	51·3 0·2	0·502 ±0·004	0·635 ±0·005	1·73	3·4 ±0·2	"	13·0 ±0·2	0·69 ± 0·02	"	0·960	0·35 ±0·02	51·7 ±0·9	67 ± 2
Succinimid $C_4H_5O_2N$	21·8°	1·41	"	0·81	2·3 ±0·1	27·88 ±1·24	35·25 ±1·57	36·34 ±1·54	2·9 ±0·2	"	23·0 ±0·5	0·62 ± 0·03	"	0·986	0·53 ±3·09	105 ±6	67 ± 299
Acetamid	22·0°	1·13	"	0·88	35·6 ±0·1	1·59	2·02	3·09	7·2 ±0·2	"	45·0 ±1	0·89	"	0·996	0·20	53·3 ±0·6	36 ± 1
Resorcinol	22 0°	1·27	"	1·04	40·3 ±0·1	0·786 ±0·003	0·995 ±0·005	1·98	3·2 ±0·2	"	11·5 ±0·5	0·67 ± 0·02	"	0·950 ± 0·004	0·24 ±0·02	24·9 ±0·3	96 ± 9
p-Toluidin	21·7°	1·12	"	0·93	50·0 ±0·1	0·481	0·608	1·72	3·0 ±0·2	"	10·0 ±0 5	0·64 ± 0 03	"	0·937 ± 0·005	0·38 ±0·03	38·0 ±0·3	100 ± 9
Acetanilid	21·8°	1·20	"	0·85	9·4 ±0·1	3·94 ±0·04	4·98 ±0·05	6·02 ±0·06	3·0 ±0·2	"	29·0 ±0·5	0·64 ± 0·03	"	0·991	0·42 ±0·14	46·2 ±1·1	105 ± 37
Naphthalene	21·5°	1·17	"	0·81	3·3 ±0·1	12·33 ±0·39	15·58 ±0·50	16·47 ±0·29	2·7 ±0·2	"	22·0 ±0·5	0·59 ± 0·03	"	0·984	0·22 ±0·82	53·8 ±3·5	51 ± 156

C_3H_7OH

	t_0	d_0'''	d_0''	d_1''	n	w_0''	v_0''	v_1''	K_0'''	K_0''	K_1''	f_0'''	f_0''	f_1''	e	Q	$A10^4$
Urethane	20·9°	1·14	0·81	0·95	52·5 ±0·1	0·695	0·863	1·94	4·0 ±0·2	18·0 ±0·5	15·51 ±0·5	0·75 ± 0·02	0·978	0·97	0·29 ±0·01	43·0 ±0·3	67 ± 3
Naphthalene	22·0°	1·17	0·80	0·82	3·8 ±0·1	13·90 ±0·38	17·28 ±0·48	18·36 ±0·46	2·7 ±0.2	"	18·0 ±0·5	0·59 ± 0·03	"	0·98	0·45 ±0·94	56·7 ±3·5	98 ± 163

$CHCl_3$

Urethane	21·2°	1·14	1·49	1·27	54·8 ±0·1	1·26 ±0·01	0·846	1·89 ± 0 01	4·0 ±0·2	4·0 ±0·2	10·5 ±0·3	0·75 ± 0·02	0·750 ±0·017	0·942	0·40 ±0·03	40·9 ±0·4	97 ± 9
Chloral hyd.	21·6°	1·90	"	1·52	19·3 ±0·1	5·73 ±0·03	3·85 ±0·02	5·02 ±0·02	3·4 ±0·2	"	6·2 ±0·3	0·69 ± 0·02	"	0·866 ± 0·010	0·76 ±0·17	38·0 ±0·9	98 ± 8
Acetanilid	21·3°	1·20	"	1·44	11·3 ±0·1	8·29 ±0 11	5·56 ±0·07	6·59 ± 0·08	3·0 ±0·2	"	9·8 ±0·3	0·64 ± 0·03	"	0·935	1·34 ±0·28	32·4 ±1·2	202 ± 49
Naphthalene	21·5°	1·17	"	1·30	30·2 ±0·1	2·52 ±0·01	1·69	2·84	2·7 ±0·2	"	3·3 ±0·2	0·59 ± 0·03	"	0·679 ± 0·004	0·08 ±0·06	36·2 ±0·4	22 ± 17
Acenaphthene	21·4°	1·20	"	1·36	21·2 ±0·1	3·45 ±0·02	2·31 ±0·01	3·42	3·0 ±0·2	"	3·7 ±0·2	0·64 ± 0·03	"	0·723 ± 0·019	0·10 ±0·14	30·3 ±0·5	34 ± 46

C_7H_8

Urethane	21·7°	1·14	0·863	0·897	19·2 ±0·1	4·96 ±0·03	5·74 ±0·03	6·80 ± 0·03	−4·0 ±0·2	2·3 ±0·2	3 0 ±0·2	0·75 ± 0·02	0·513 ±0·045	0·640 ± 0·029	0·66 ±0·49	21·5 ±0·8	315 ± 240
Chloral hyd.	21·9°	1·90	"	0·979	13·1 ±0·1	7·01 ±0·07	8·12 ±0·08	9·10 ± 0·08	3·4 ±0·2	"	3·0 ±0·2	0·69 ± 0·02	"	0·640 ± 0·029	1·23 ±0·48	40·0 ±1·4	312 ± 131
Naphthalene	22·6°	1·17	"	0·912	22·5 ±0·1	2·89 ±0·02	3·35 ±0·02	4·45 ± 0·02	2·7 ±0·2	"	2·8 ±0·2	0·59 ± 0·03	"	0·609 ± 0·033	0·40 ±0·35	49·0 ±0·8	83 ± 73
Acenaphthene	22·0°	1·20	"	0·915	15·4 ±0·1	3·94 ±0·03	4·57 ±0·03	5·62 ± 0·03	3·0 ±0·2	"	2·8 ±0·2	0·64 ± 0·03	"	0·609 ± 0·033	0·44 ±0·46	32·1 ±0·9	141 ± 147
Phenanthrene	21·7°	1·18	"	0·931	21·0 ±0·1	2·29 ±0·01	2·65 ±0·01	3·73 ± 0·01	2·9 ±0·2	"	2·3 ±0·2	0·62 ± 0·03	"	0·513 ± 0·045	−0·6 ±0·32	21·3 ±0·5	−24 ± 150

Collecting for discussion, including the vaporization data, we have

		Δ	Δ²	
140		+ 44	1936	140 − 72 = 68
175		+ 79	6240	175 − 72 = 103
154		+ 58	3364	154 − 72 = 82
44	± 4	− 52	2704	44 + 72 = 116
50	± 4	− 46	2116	50 + 72 = 122
125	± 8	+ 29	841	125 − 72 = 53
48	± 28	− 48	2304	48 + 72 = 120
36	± 0	− 60	3600	36 + 72 = 108
82	± 6	− 14	196	82 + 72 = 154
76	±190	− 20	400	76 + 72 = 148
28	± 48	− 68	4624	28 + 72 = 100
60	± 4	− 36	1296	60 + 72 = 132
114	± 22	+ 18	324	114 − 72 = 42
145	±559	+ 49	2401	145 − 72 = 73
64	±211	− 32	1024	64 + 72 = 136
52	± 4	− 44	1936	52 + 72 = 124
67	± 2	− 29	841	67 + 72 = 139
67	±299	− 29	841	67 + 72 = 139
36	± 1	− 60	3600	36 + 72 = 108
96	± 9	± 0	0	96 = 96
100	± 9	+ 4	16	100 − 72 = 28
105	± 37	+ 9	81	105 − 72 = 33
51	±156	− 45	2025	51 + 72 = 123
67	± 3	− 29	841	67 + 72 = 139
98	±163	+ 2	4	98 − 72 = 26
97	± 9	+ 1	1	97 − 72 = 25
98	± 8	+ 2	4	98 − 72 = 26
202	± 49	+106	11204	202 − 72 = 130
22	± 17	− 74	5475	22 + 72 = 94
34	± 46	− 62	3844	34 + 72 = 106
315	±240	+219	47950	315 − 72 = 243
312	±131	+216	46660	312 − 72 = 240
83	± 73	− 13	169	83 + 72 = 155
141	±147	+ 45	2025	141 + 72 = 69
−24	±150	−120	14400	−24 + 72 = 48
96 = Mean			174287 = $\Sigma\Delta^2$.	

The mean error of a single determination is therefore

$$\sqrt{\frac{174287}{34}} = \sqrt{5126} = \pm 72$$

and the mean error of the mean, 96, is

$$\frac{72}{\sqrt{35}} = 12.$$

The probable errors for single determinations and for the mean determination are respectively

$$\tfrac{2}{3}72 = 48 \text{ and } \tfrac{2}{3}12 = 8.$$

At first inspection these figures are discouraging, but when we find the mean error of a single determination to be 72 and then find that this mean error will more than bring 29 out of the 35 determinations into the mean of the whole, namely 96, and that 5 of the 6 exceptions have experimental errors of their own more than sufficient to bring them also into the mean, and that the other one has an unknown experimental error, the final result is not so bad and there is nothing to disprove the correctness of equation 4 and the constancy of the quotient e/Q. In other words, that the heat of a change comes from a change in the field surrounding us and that this change is measured by the dielectric constants of the components of the system, is an assumption in agreement with the foregoing experiments.

Rutgers College, New Brunswick, N. J.
February, 1903.

ART. VII.—*Some Notes on the Genus Baptanodon, with a Description of a New Species;* by WILBUR C. KNIGHT.

IT was many years ago that Marsh described Baptanodon (Sauranodon*), and with the exception of a very short paper† by the same author in which he describes a new species, nothing has been written to give us a better understanding of the peculiar American Ichthyosaur until Charles Gilmore published some additional and valuable information very recently in Science.

Yet we do not know very much about this peculiar swimmer, and a great deal of information is desirable before it will be possible to say with any certainty, whether there is any great difference between Baptanodon and Opthalmosaurus or not. Several paleontologists have already expressed themselves in the belief that these genera are identical. For a number of years specimens have been accumulating in the collection of the University of Wyoming, and from these some valuable points have been secured. From what I know of Baptanodon I am in favor of retaining the name. In the following notes will be found some argument favoring this generic name and showing how that Baptanodon differs from Opthalmosaurus.

Front Limb of Baptanodon.—Humerus about one-third the length of the limb, with a stout twisted shaft that is greatly compressed near the distal end. Planes passed through the articulate ends of the humerus stand at an angle of 50°. The head is slightly rounded and is almost identical with Ichthyosaurus. There are three distal facets; but they are not of equal size. The facet for the ulna is the largest, the one for the radius next in size, and the one opposite the pisiform is rudimentary, for that bone was held in cartilage and did not articulate with the humerus. These facets are elliptical in form, and those opposite the ulna and radius elongated in the plane of articulation in place of being vertical to it, as they are in Opthalmosaurus. The radius is a subangular bone, with the exterior margin reduced to a thin edge that is nearly straight. It is also larger than the ulna, which is slightly hexagonal in shape. The pisiform is subcircular in form and is the smallest bone of the second segment of the limb. The next segment is composed of four subcircular bones as noted by Marsh, but the succeeding row is composed of only three bones. The largest appears to have been formed by the consolidation of three elements. This might have been considered as an indi-

* This Journal, xvii, 85. † Ibid., xix, 169, 491.

vidual characteristic had I not found it in at least three animals. The limb that I have been studying and have figured differs from the one published by Marsh, inasmuch as the abnormal number of digits do not appear until the phalanges are reached, and then by a division of the third digit. This information has been secured from a specimen in the matrix and is absolutely reliable. The carpals, metacarpals and phalanges are compressed grooved cylinders, the most of which have slightly concave surfaces. The grooves are ornamented with tuberosities for muscular attachment. Along the margins of the limb the cylinders have their exterior borders reduced to quite thin edges. Any one finding the limb of a Baptanodon for the first time scattered about in the field would surely

FIGURE 1. C.—Transverse section of an interior carpal; D.—Terminal carpal; E.—Marginal carpal. All reduced one-half.

try to fit the ventral and dorsal surfaces of the metacarpals together in trying to construct a digit.

In comparing the limbs of Opthalmosaurus and Baptanodon one should consider the following points: In Baptanodon the humerus is about one-third the length of the arm; it has a twisted shaft which is greatly compressed. The distal facets are all unequal in size and one of them is merely rudimentary, besides they are elliptical in the plane of articulation. There is also an abnormal number of digits, and the arm is much more powerful and larger than found in Opthalmosaurus of equal size. The indications are that Baptanodon was a remarkable swimmer.

Hind Limb.—The hind limbs in the collection are too fragmentary to admit of accurate determinations. The femora examined all have two facets only. I was not satisfied with

2

FIGURE 2.—Right pectoral limb, dorsal aspect, reduced about 2½ times.

the material in hand and wrote Dr. Beecher concerning the material at Yale University, and he informed me that the ones examined by him in the Yale collection had but two facets, and that the humerii had three but one was very small. The fact that Baptanodon so far as known has but two elements articulating with the femora is worthy of special consideration.

Vertebral Column.—The specimen S in the Wyoming collection contains 41 precaudal vertebræ. These are consecutive and represent the series from the head backwards. The atlas and axis are so completely fused that there is not the slightest trace of their union. Anteriorly the first vertebra (atlas and axis) is only slightly excavated; but upon this elongated vertebra there are two normal or almost normal processes. The first vertebra (atlas and axis) is 41^{mm} in length, and the second is only 31^{mm} long. There is no intercentra between these (the second and third) vertebræ. It is also questionable whether there is any between the atlas and axis and the axis and the basiocipital. If they are present they are so perfectly anchylosed to the centra as to make it impossible to distinguish them. I have only examined a single specimen, and while I think it possible that all of the intercentra have disappeared, it will be desirable to make further examinations before this point can be passed upon. In specimen S the vertebræ gradually increase in length and width from the atlas and axis to No. 19; the third vertebra being 31^{mm} long and 80^{mm} wide and the nineteenth 41^{mm} long and 90^{mm} wide. These are separated by intercentra measuring from 10 to 15^{mm}. From No. 19 backwards to the end of the series the vertebræ decrease slightly in length and width. In specimen T in the same collection there are 46 consecutive caudal vertebræ. These are of the usual ichthyosaurian type, and represent an animal that had an extremely long and slender tail. The reduction in the size of the vertebræ occurs very near the body and within a distance of a few inches the vertebræ decrease in diameter over one-half. The vertebræ in the area of reduction have reduced margins, in fact in two of them the articulations nearly meet upon the side of the centrum. This signifies that the tail was extremely flexible near the body, which would make it of great value in swimming, and without question this animal could lash its sides with its tail. I have not noted anything of this kind in the genus Ichthyosaurus. Although caudal vertebræ from at least a half dozen different animals have been examined, no trace of chevrons has been observed, and the vertebræ lack chevron facets.

Pectoral Girdle.—The coracoids are broadly elliptical bones, anteriorly deeply and broadly notched; posteriorly circular. They thicken rapidly from the center to the interior margin

of the anterior half into a large elliptical facet with a rugose surface. A facet measured 81 by 123mm. These facets unite on the median symphysis, which must have made the girdle very ridged during life. There was no evidence of an inter-

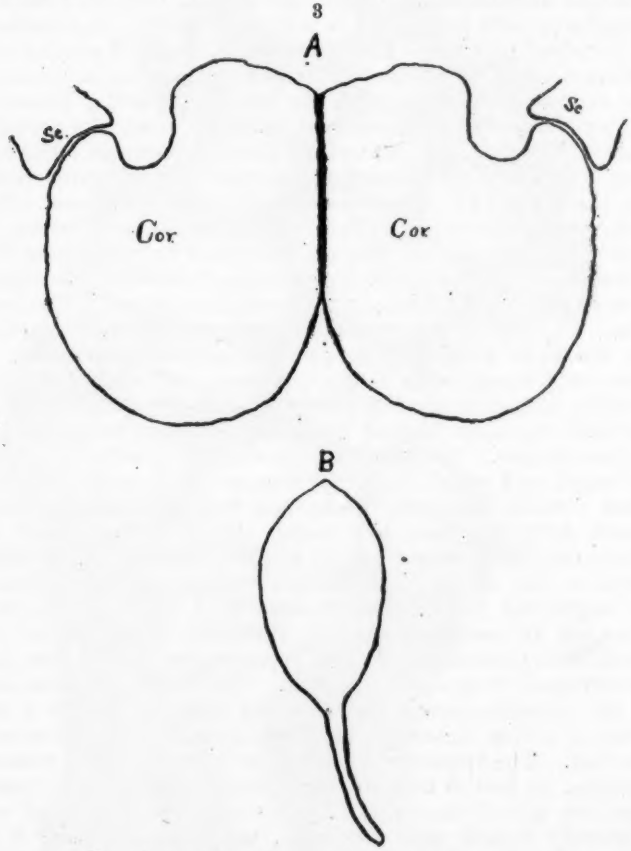


FIGURE 3. A.—Pectoral girdle incomplete, about $\frac{1}{3}$ natural size; B.—Outline of the interior margin of coracoid, about $\frac{1}{4}$ natural size.

clavicle, and the peculiar union of the coracoids precludes an interclavicle of the regular Ichthyosaurian type. In consequence the interclavicle in Baptanodon must be considered rudimentary or wanting. The scapulæ are rather heavy bones, with broad notched proximal ends, that fit the projection of the coracoids between the anterior notch and the glenoid cavity. Clavicles are unknown to me.

The most of the above information has been taken from the S skeleton of the Wyoming collection, and I have found it impossible to include this in the species already described and for that reason propose the name of *Baptanodon Marshi*, in honor of Prof. O. C. Marsh, who originated the generic name Baptanodon. The accompanying figure of a front limb can be considered as typical for this species.

Some Measurements for Baptanodon Marshi.

	M.
Humerus.	
Length	·190
Prox. width	·127
Prox. thickness	·080
Distal width	·130+
Distal thickness	·050
Facet for ulna, length	·080
Facet for radius, length	·050
Facet for pisiform, length	·010?
Ulna,	
Width	·069
Length	·054
Radius,	
Width	·065
Length	·046
Pisiform,	
Width	·036
Length	·054
Coracoid,	
Length	
Width	
Median facet,	
Length	·123
Width	·081

In comparing Baptanodon with Opthalmosaurus it will be well to consider that in Baptanodon the interclavicle is either rudimentary or wanting, the absence of the intercentra between the second and third vertebræ, the development of the large facets upon the interior margins of the coracoids, the striking differences in the development of the limbs, causing Baptanodon to have been a much more powerful swimmer than its European ally.

Geological Laboratory, University of Wyoming.

ART. VIII.—*The Characters of Pteranodon;* by G. F. EATON. (With Plates VI and VII.)

A CAREFUL preparation of Pterodactyl material from the Niobrara Cretaceous of western Kansas has been commenced at the Yale University Museum, for the purpose of adding an example of one of the gigantic species of the genus *Pteranodon* Marsh, to the series of restorations of fossil vertebrates recently attempted with success. Preparatory to this work, a critical examination both of the fossils themselves and of the literature based upon them has been made, and an excellent opportunity has been thus afforded to extend our knowledge of the skeleton of *Pteranodon*, in regard to several important points of structure. This, in turn, may be of great value in determining the true position of the genus among the Pterodactyls.

The large collection of these reptiles made by Prof. Marsh and his assistants in the field, during a period including the years 1870 to 1894, and representing, according to Prof. Marsh, the fossil remains of more than six hundred individuals, was never completely examined and described by him. His series of papers upon this unique order, which appeared in this Journal, 1871 to 1882, were, at the time of publication, considered by him as little more than preliminary notices. No detailed work on the American Pterodactyls ever issued from his hands, as his attention was constantly diverted by the acquisition of other and not less valuable vertebrate fossils.

His researches both in field and in laboratory having awakened the interest of the scientific world in the Kansas Pterodactyls, it is not surprising to find other collectors and authors engaged in similar investigations. While part of Prof. Marsh's earlier work on this group was performed in a somewhat hurried manner, the accuracy with which he seized upon important osteological characters is amazing. In one instance, at least, his opinion, after having been disputed almost to the point of ridicule, proves to be much more correct than that advanced by his critic. Considering his great talent and the abundance of material at his command, it is to be regretted that Prof. Marsh did not pursue the study further before laying it aside. Had he done so, he would have prevented the misconceptions which have lately gained credence.

The Sagittal Crest.

The most important correction to the prevailing idea of *Pteranodon* is to be made in regard to the sagittal crest. Prof. Marsh in describing the skull makes use of the follow-

ing words (this Journal, vol. xxvii, May, 1884): "an enormous sagittal crest extends far backward, and somewhat upward." The accuracy of this statement is denied by Prof. S. W. Williston (Kansas Univ. Quarterly, vol. i, No. 1, July, 1892), whose views have been accepted largely because of the fact that he collected the head of Marsh's type of *Pteranodon*. Material in the Yale Museum now shows that, contrary to Williston's opinion, the elongation of the crest, as figured by Marsh, was too conservative. Reference to Plate VI, figure 1, will show its true form, taken from an actual specimen, which is indicated by the continuous line. Marsh's incomplete restoration is shown by the dotted line, while Williston's figure of the skull, shorn of its crest, is reproduced carefully in figure 2. Prof. Marsh laid emphasis on this character, and it is of great importance that this error be corrected at once. Following Williston's lead, Dr. S. P. Langley and Mr. F. A. Lucas, both of the Smithsonian Institution, have perpetuated the error in their respective papers in the Annual Report of that Institution for 1901.

In justice to Williston, it is perhaps only fair to quote him verbatim (loc. cit.): "As stated by me in the American Naturalist, the type specimen of *Pteranodon*, also collected by myself, was incomplete, and the figures of it, as given by Marsh, are faulty." This statement can not be gainsaid. The type suffered through the rough methods of collecting employed in those days; but the following clause has been shown above to be incorrect: "The sagittal crest is large, but not nearly so large as it is figured by Marsh, the outline of whose figure is undoubtedly wrong."

To assign the cause of mistake on the part of another writer may be considered a work of supererogation, yet I am tempted to offer here a possible explanation of Williston's misinterpretation of the sagittal crest of this reptile. At the present time of writing, an incomplete Pterodactyl skull is being worked out at the Yale Museum, which will in all probability prove to be that of *Nyctodactylus* Marsh. The crest, which is apparently entire, is of small size compared with that of *Pteranodon*, the measurement from occipital condyle to tip of crest being only 49^{mm}, while the length from occipital condyle to tip of beak was approximately 47^{cm}. In general, the skull compares favorably with that shown in Williston's restoration of *Nyctodactylus* given in the American Journal of Anatomy, vol. i, No. 3, May 26, 1902, where he states that the outline is taken in part from a specimen of *Pteranodon* Marsh, or *Ornithostoma* Seeley, as the genus was then called. It is therefore fair to infer that the apparent similarity of the two genera led Williston to draw uninten-

tionally upon the characters of *Nyctodactylus* when making his restoration of *Pteranodon*.

The Suspensorium.

Another remarkable character of the skull of *Pteranodon*, which belongs apparently to *Nyctodactylus* also, is the articulation of the mandibles with the quadrates. The distal end of each quadrate has the form of a spiral groove, left-handed in the right quadrate and right-handed in the left. The articular elements of the mandibles have a reciprocal form. So perfect is the mutual adjustment of these parts that, unless actual dislocation took place, the act of opening the mouth must have resulted either in a considerable widening of the lower jaws posteriorly or in the forcing together of the quadrates. Apparently the pterygoids and palatines serve as a rigid and immovable support to the quadrates, a condition which would render movement of the latter impossible. In such case an expansion of the lower jaws is, in my judgment, the only way by which the lateral motion caused by the spiral articulation could be taken up mechanically; and this in the face of the seemingly inflexible mandibular symphysis and the thorough union of the mandibular elements.

The existing vertebrate offering the closest parallel in this respect to *Pteranodon* is the Pelican. A careful inspection of the suspensorium of this peculiar bird reveals a similar spiral articulation between quadrates and mandibles, and it is recorded that in the Pelican the act of opening the mouth results also in the widening of the jaws posteriorly. There has been some speculation in regard to the habits of the American Pterodactyls, but no definite conclusions have yet been reached. Possibly the mechanical similarity between the mandibular suspensorium of the Pelican and that of *Pteranodon* is to be received as evidence of the possession of a gular pouch by this Pterdactyl as well as by the bird.

Mr. Lucas has apparently arrived at the same conclusion along another line of evidence. He says (loc. cit.): "In the peculiar shape of the lower, back portion of the beak there is a suggestion of the former presence of a small pouch, like that found in cormorants, and this would be in accord with the supposed fish-eating habits of *Ornithostoma*" (*Pteranodon* Marsh).

The Pelvis.

A nearly perfect pelvis, recently worked out at the Yale Museum, throws much light on the discussion of the characters of this important part of the skeleton of *Pteranodon*, which has not been thoroughly understood and described by

paleontologists. Three diagrams of this specimen are here given, showing the side, top, and bottom views (Plate VII, figures 1, 2, and 3, respectively). It is not my intention at this time to enter into a detailed description of the pelvic characters. Indeed, at present, it is necessary to publish little more than the diagrams, which may prevent any further serious misinterpretation of the pelvis.

Ten vertebræ firmly anchylosed together form the sacral series, using this term in its broader sense. The upper ends of the neural spines of all these vertebræ are united in a continuous ridge about 9^{mm} wide and about 6^{mm} in vertical depth (Plate VII, figure 1). The general form of the transverse processes of the three anterior vertebræ in this series, and their union with the ilia, are sufficiently well shown in the accompanying diagrams (Plate VII, figures 2 and 3). The first vertebra bears anterior zygapophyses for articulation with the last free dorsal; and the transverse processes of the first three vertebræ have on their lower surfaces small facets for the support of ribs. One of these posterior ribs still lies upon the third vertebra, with little displacement from its original position. The transverse processes of vertebræ 4, 5, 6, and 7, depart widely from the foregoing simple arrangement. They are likewise separated by large foramina, but they unite again laterally and form a continuous support for the ilia. The lower ends of the transverse processes of vertebra 4 extend downward and backward, as stout buttresses, finally becoming confluent with the inferior margins of the ilia. The three remaining vertebræ, numbers 8, 9, and 10 of this series, bear short transverse processes, separate at their distal ends, upon which the ilia rest posteriorly.

The ilia extend forward as broad, thin blades, supported, at their inner margins, by the transverse processes of the anterior sacral vertebræ. Posteriorly they unite over the neural spines of the last three sacrals, and are anchylosed to them as well as to the transverse processes. The united pubes and ischia are directed downward and backward, and meet below in a long median symphysis. The obturator foramina lie just beneath the imperforate acetabula. They are circular in form, of about half the diameter of the acetabula, and may be considered as marking the theoretical line of fusion between the true pubic and ischial elements. On the anterior border of these ischiopubic expansions are small facets, which undoubtedly served for the attachment of prepubes. In no specimen in the Yale Collection has a prepubis yet been found in place.

Paleontologists will perhaps disagree on the number and position of true sacrals in *Pteranodon*. It will be remembered that Huxley, when confronted with a similar problem in

the avian sacrum, chose the intervertebral foramina as the best criteria for distinguishing true sacrals from sacro-dorsals and uro-sacrals. In the present fossil specimen there are, of course, no nerves to serve as guides, but I hope to show in a subsequent paper that vertebræ 5, 6, and 7, which clearly form a natural division, are the true sacrals. Vertebra 4 may prove to be the homologue of the last lumbar vertebra in the sacrum of recent birds. In closing I should like to state, with due apologies to Prof. Lydekker, that the "parallel" between the sacrum of *Pteranodon* and that of recent birds is striking, though I have no desire to postulate "converging lines" of structure and descent.

Paleontological Laboratory, Yale University Museum,
June 8, 1903.

EXPLANATION OF PLATES.

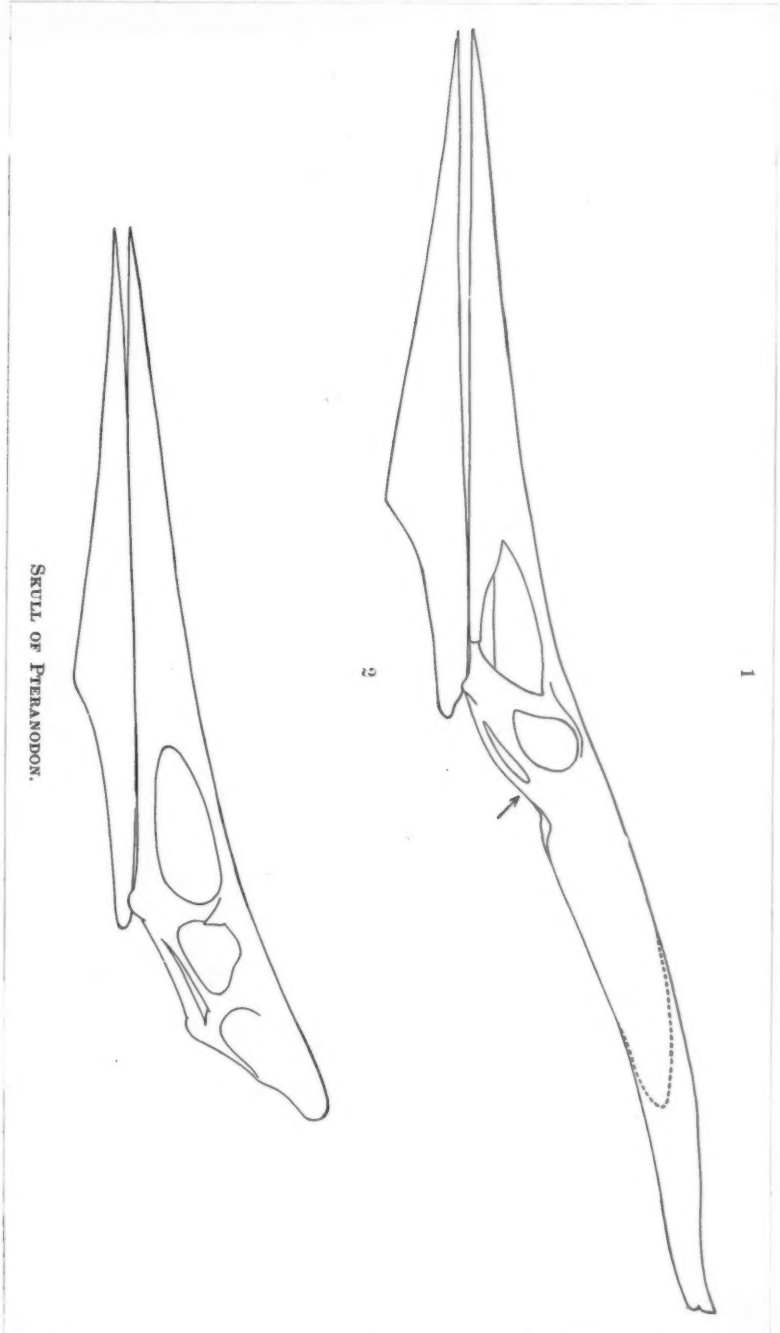
Plate VI.

Figure 1.—Restoration of skull of *Pteranodon*.
True outline of sagittal crest is shown by continuous line. Marsh's restoration of sagittal crest is shown by dotted line. One-sixth natural size.

Figure 2.—Enlargement of Williston's diagram of skull of *Pteranodon*. Approximately one-quarter natural size.

Plate VII.

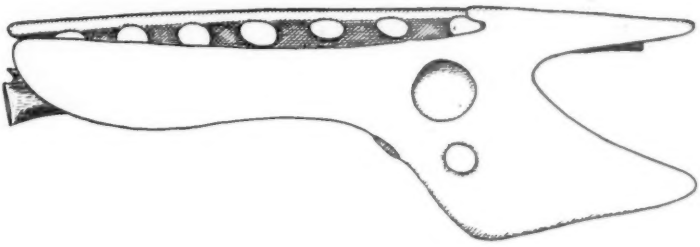
Figure 1.—Pelvis of *Pteranodon*; side view.
Figure 2.— " " ; top view.
Figure 3.— " " ; bottom view.
All three figures are one-half natural size.



SKULL OF PTERANODON.

2 1

1



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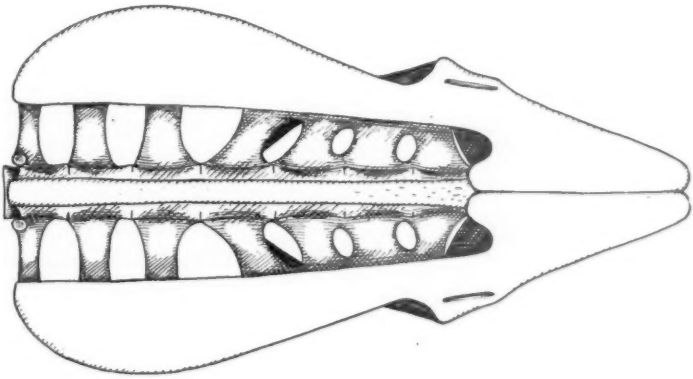

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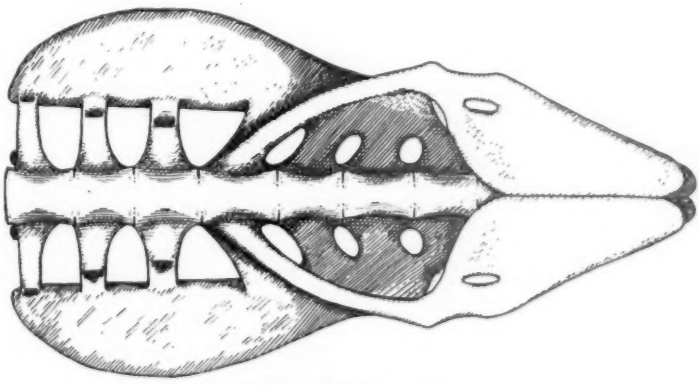
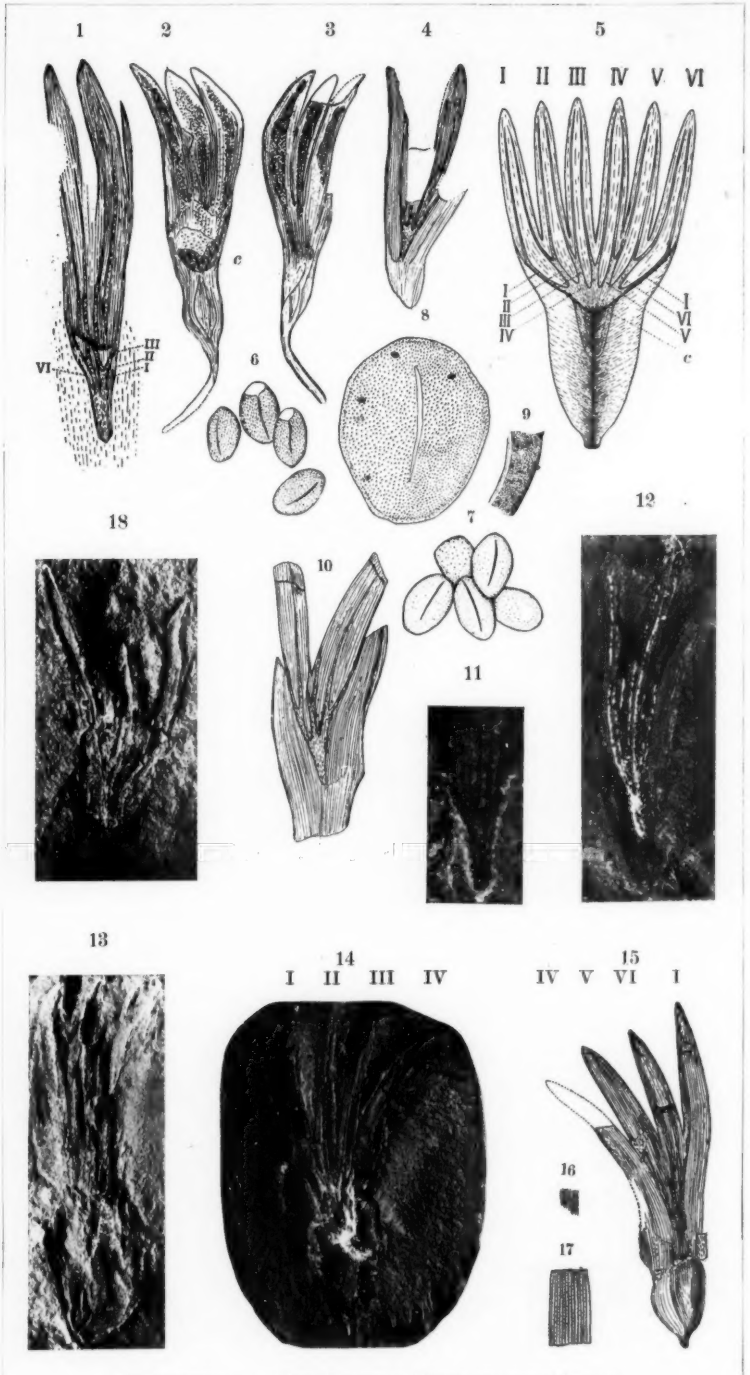


PELVIS OF PTERANODON.



CODONOTHECA, A NEW TYPE OF SPORE-BEARING ORGAN.

ART. IX. — *Codonotheca, a New Type of Spore-Bearing Organ from the Coal Measures;** by E. H. SELLARDS. (With Plate VIII.)

THE iron-stone nodules of Mazon Creek, Illinois, which have preserved so many interesting fossils, contain not infrequently an isolated, but unique, and as yet undescribed type of fructification. The conditions of preservation in these nodules are such that by careful developing it is possible to make out many of the details of structure of the fossils contained in them. In the present case, the abundance of material at hand, and the unusual organization of the reproductive organ give an especial interest to the study. It is the purpose of the present paper to describe the structure of this peculiar type, in so far as the material at hand will permit, in the hope that a description of the fructification will lead to its recognition in collections from other localities in this and foreign countries, and to the determination of the plant to which it belongs. The collections from the Mazon Creek locality in museums, especially of this country, are generally quite extensive and some of these may be found to contain specimens throwing new light on the relation of this fructification.

The spore-bearing organ is a symmetrical cup- or bell-shaped body, made up of a circle of six equidistant, lamina-like, spore-bearing divisions, arising at a common level, united laterally at the base, free at the tips, thus surrounding a central cavity; each division is traversed on the inner or spore-bearing side by two strong bundles supplied by the dichotomy of six main strands; the union of the laminæ and bundles below forms a cylindrical base, while the whole organ is borne on a slender petiole. The base, which seems to have consisted for the most part of an external envelope of non-resistant fleshy tissue, is usually more or less completely flattened in the fossil condition. It is traversed by lines, often wavy and irregular, lying near the surface and extending along the dorsal side of the spore-bearing divisions, probably representing subepidermal bands of strengthening tissue. The fusion of the six main vascular strands forms a cone-shaped area of resistant tissue at the center of the base, large at the top where it breaks up into strands, pointed below where it is replaced by less resistant tissue. This area occasionally retains its cylindrical shape (figs. 1 and 11, Pl. VIII). The six strands originating at a common level from this central area diverge and dichotomize also at approximately the same level. The twelve bundles formed by this dichotomy pass into the six spore-bearing divisions, which

* Abstracted from a thesis submitted to the Graduate Faculty of Yale University, May, 1903, for the degree of Doctor of Philosophy.

for convenience will be spoken of in this paper as spore-bearing segments, or simple segments. The distribution of the bundles to the segments is characteristic. Each individual segment is supplied not by the two bundles resulting from the dichotomy of a single main strand, but receives one bundle from each of two adjacent strands (compare figs. 1, 4, 11, 15, and the plan of structure, fig. 5, Pl. VIII). This peculiarity in the arrangement of the bundle system can be verified from numerous specimens, and is one of the prominent structural features of the organ of fructification. The free tips of the segments occasionally stand open, thus retaining in part their original shape, owing probably to their having been quickly buried in sediment. By carefully removing the matrix which fills the cone-shaped cavity enclosed by the segments, it is possible to examine the six parts in place. The two figures, 14 and 15, illustrate a specimen worked out in this way, as seen from the two sides. The matrix filling the cavity formed by the expanded segments was removed intact and has the shape of a cone flattened laterally, on which is preserved the impressions of the six spore-bearing segments. On refitting the two parts of the nodule together, there results an elliptical cavity, large at one end corresponding to the top of the organ, and becoming smaller and disappearing toward the crushed base. The shape of the organ is thus partly preserved in this nodule, being simply compressed laterally. On looking into the cavity a very satisfactory idea of the shape and arrangement of the parts, and of the whole organ as it appeared in life is obtained. The outline restoration of this fructification given in the accompanying text figure is based on this and similar specimens. The plan of structure of the organ (fig. 5, Pl. VIII) represents the hollow top as unrolled and the solid base as cut through the center and laid open. The section is made to pass between segments I and VI, hence directly through strand number I. The letter *c* marks the bottom of the cavity enclosed by the segments.

Codonotheca; restoration of the spore-bearing organ. Natural size.

Considerable variation in size is evident in the series of specimens. Those of an average size measure 3 to 5^{cm} from the base to the tips. The width at the top is about 1$\frac{1}{8}$^{cm}. The segments above the point where they become free are 1$\frac{1}{2}$ to 2^{cm} long and 2$\frac{1}{2}$ to 3^{mm} wide. The petiole is incomplete, the longest

observed being a little over 1^{cm}. When well preserved the petiole shows a netlike structure made by strong longitudinal striæ and weaker cross lines, suggesting the structure occasionally seen on the leaves of some *Cordaites* (fig. 16, Pl. VIII).

Spores.—Much interest is attached to the presence of the spores and the position in which they lie. In the best-preserved specimens the spores lie over the segments from the tip to the base, and seem to be confined to a more or less well-marked depression occupying one-half or two-thirds the width of the segment. In such spore-bearing segments as are crushed laterally, at the side of the fossil, the spores are pushed to the inner side, indicating that they were contained in sporangia or chambers near the inner surface, and apparently were not, as might otherwise have been thought possible, held loosely in a central cavity of the segment after the manner of moss sporogonia; in the latter case the spores would appear along the center line of the segment, however crushed. There is no grouping of the spores or other indications of the location of sporangia, which were doubtless more or less completely immersed in the tissue. In order to contain even a few of these large spores the sporangia would necessarily be of large size and if external in position would probably have left definite impressions in the stone, as do the sporangia of most other plants in these nodules. The spores seem to have been scattered somewhat, owing probably to the disappearance of the walls of the sporangia at maturity, so that in the fossil they run together and entirely fill the depression in which they lie.

From the position of the spores, the sporangia appear to have been located along the vascular bundles. Inasmuch as they have not been seen, no attempt is made to represent them in the restoration. The spores are large, elongate-elliptical, 0·29 to 0·31^{mm} long and 0·18 to 0·20^{mm} wide. They are brown in color, somewhat flexible, and section readily on the microtome.* The spore wall consists of an inner, compact layer, and an outer much thicker layer which appears granular in microtome sections seen under a high power. A slit is usually present in the side of the spore, apparently indicating bilateral division from the spore mother-cell. The spores occasionally contain small round grains with dark centers, doubtless representing a part of the original food supply. In size and shape, the spores rather closely resemble those of *Dolerophyllum*, except that there is but a single slit in the side, instead of two furrows as described for that genus. The spores (pollen grains) of *Dol-*

* The spores may be imbedded by the ordinary methods; less time, however, is necessary for dehydrating, and the paraffin bath may be brought to any desired temperature.

erophyllum are contained in a boxlike excavation in the fleshy tissue of the reduced leaf.* There is apparently nothing in the structure of the spore itself, as preserved, to determine whether the plant was homosporous or heterosporous. From their large size the spores might be taken for megaspores. Bilateral megaspores, however, although seemingly occurring rarely, are exceptional among vascular cryptogams. A careful search has been made through all the available material, amounting to about seventy-five specimens (with in most cases their counterparts), many of which have the spores preserved, but no evidence of two kinds of spores has been found. This negative evidence, although hardly conclusive, is entitled to considerable weight. In view of the abundance of material, the chances are very great that if two kinds of spores existed both would be present. The conclusion that the plant was homosporous is, therefore, reasonably certain, unless the second kind of spore proves to have been borne by a differently constructed organ.

The generic name *Codonotheca* is proposed for this type of spore-bearing organ. The type species here described may be known as *Codonotheca caduca.*

Botanical Relations.—The botanical relations of this unusual fructification are as yet very uncertain. The spore-bearing organ seems to have been readily deciduous, and thus far has not been found in connection with the vegetative part of the plant. Two of the fossils lie side by side on one of the nodules in such a way as to indicate that both were probably attached by long petioles to a common stem. At one side and at a slightly lower level is seen a slender striated stem; but the actual connection is not preserved. Three other specimens lie near each other on the same nodule. It has been assumed in the above description that the six parts of the organ are sporangia-bearing divisions. A second hypothesis may perhaps suggest itself, namely, that the parts are themselves enormous sporangia united at the base somewhat after the manner of such genera as *Botryopteris*, *Zygopteris*, and some of the small species referred to *Calymmatotheca.* Their great size and especially the presence of well-developed vascular strands running through them is, however, much against, if not fatal to, such a supposition. Even a slight development of vascular tissue within the walls of a sporangium is unusual, although such may occasionally occur, as shown in a recent paper by Prof. F. W. Oliver.† It seems hardly possible, therefore, that the spore-bearing segments can be individual sporangia, because of their large size and especially the prominence of the vascular

*Renault, Bassin houiller et Permien d'Autun et d'Epinac, p. 266, 1890.

†On a Vascular Sporangium from the Stephanian of Grand Croix, The New Phytologist, vol. i, p. 60, March, 1902.

strands running through them. On the contrary, the organ appears to be made up of six lamina-like fertile divisions, united in a circle at the base so as to enclose a central cavity, the sporangia being borne on the inner side and probably partly or entirely immersed in the fleshy tissue.

It seems wholly improbable that *Codonotheca* can have any direct or close connection with the mosses or other plants lower in the scale of development than the vascular cryptogams. It is true that a water-conducting tissue is rather well developed in the stem of some mosses, and to some extent in the sporogonia of a few genera, but a well-developed vascular system, such as this organ possesses, is at present entirely unknown in any plant below the Pteridophytes. On the other hand, the unusual structure of the reproductive organ makes it difficult to determine the systematic position of the genus among the vascular plants. The spore-bearing region of the known Paleozoic and recent Equisetales is typically a cone formed by the shortening of the internodes of the main axis, or of the axis of a branch. The cone is made up of several to many nodes and internodes. Each node may bear a whorl of fertile sporophylls, or fertile and sterile whorls may alternate or be variously modified according to the genus. In the extinct Sphenophyllales, the cone is also formed by a shortening of the internodes of the axis, and the fertile sporophylls are borne in whorls at the nodes. The sporangia of the Lycopodiales are borne at the base of the sporophylls, which usually form a cone. The ferns, although a more varied class, seem to include no type whose fundamental structure is comparable to that of *Codonotheca*. Some species of *Schizæa*, as *S. pennula*, have a cluster of similarly shaped sporangia-bearing divisions, but these have external dorsal sporangia with a ring of thick-walled cells at the top, and lack entirely the unusual cyclic arrangement and the fleshy petiolate base characteristic of *Codonotheca*. It is also evident that this new type can have no connection with such ferns as the Hymenophyllaceæ, in which the elongated receptacle, bearing the sporangia, is surrounded by an indusium-like outgrowth of the lamina. The extinct fernlike genera *Botryopteris* and *Zygopteris*, which have sporangia clustered at the ends of slender peduncles, do not seem to admit of comparison with *Codonotheca* except on the hypothesis, which appears to me untenable, that the six divisions of the organ are so many large sporangia.

For many years numerous plants have been known from the Paleozoic, having a stem structure resembling that of the ferns on the one hand, and the cycads on the other, but so different in many ways from both as to be with difficulty included in either. Since 1899* these plants have been united to form an

* Potonié, Lehrbuch der Pflanzenpalaeontologie, p. 160.

intermediate group, the Cycadofilices, the more generalized divisions of which are believed to form, to some extent at least, a connecting series between the ferns and cycads. The stem structure indicates considerable diversity among the several divisions of the group. Unfortunately hardly anything is known of the fructification. Certain sporangia of the *Calymmatotheca* type have been found so closely associated with one genus of the Cycadofilices, *Lyginodendron*, as to make their connection probable.* *Lyginodendron* has finely divided foliage, and is one of the more fernlike of its class. The small species of *Calymmatotheca* found in association with *Lyginodendron* have large sporangia grouped in a cluster at the end of a petiole, free at their tips, free or united at their bases, and borne on dimorphic fronds. A number of other plants of various structure have been referred to *Calymmatotheca*. The largest of these and also the first described species of the genus, *C. Schimperi* Stur, is an imperfectly known fossil. According to Stur† the plant consists of six parts, 18^{mm} long, united at the base by threes, and is apparently entirely different from many of the smaller species which have been referred to the genus.

Aphlebiocarpus Stur is another imperfectly understood genus of unknown affinity.‡ This remarkable fructification consists of about five foliar parts, more or less deeply lobed or fringed, arranged in an involucre-like whorl. According to Stur, the sporangia are small, solitary, and deep set, and are placed thickly over the upper or inner surface of the "involucre." The spores are not described, and the vegetative part of the plant, except for the branching axis, is unknown.

Codonotheca suggests at first sight a possible resemblance to the male flowers of some gymnosperms. *Tumboa (Welwitschia)* has microsporophylls united in a circle at the base. The microsporophylls of the Mesozoic Bennettitaceæ, also, as Wieland has shown, are fused in a circle at the base. But the relation to these genera is probably not close, since the Bennettitaceæ, as well as *Tumboa*, seem to have an abortive, seed-bearing cone at the center.§

While the genus may find its place as an aberrant type among one of the well-known classes of Pteridophytes or even gymnosperms of Cordaitalean affinity, it may on the other hand

*Scott, Studies in Fossil Botany, pp. 334–336; Benson, Ann. Bot., vol. xvi, pp. 575–576, 1902.

†Die Culm-Flora der Ostrauer und Waldenburger Schichten, Abhandl. der k. k. geol. Reichsanst. zu Wien, vol. viii, p. 149, 1877.

‡Ibid., p. 304, pl. 37, 1877; Die Carbon-Flora der Schatzlaren Schichten, ibid., vol. xi, Abth. I, p. 15, 1885.

§Wieland, A Study of Some American Fossil Cycads, pt. iv, This Journal, vol. xi, p. 424, 1901.

prove to fall within the comparatively varied but less well-known Cycadofilices, as representative of a specialized division at present included in that group and which has suffered extinction. The plants to which the *Codonotheca* type of fructification belongs, as far as the arrangement of their spore-bearing organs is concerned, seem to have reached a comparatively specialized condition as early as the Upper Carboniferous. There are present in the Coal Measures and at the Mazon Creek locality several genera or groups of plants, the fructification of which is either unknown or but imperfectly understood. Conspicuous among these, both from its large size and great abundance, is *Neuropteris*, especially the large species, *N. decipiens* Lesqx. Renault* and others have shown that the petiole of *Neuropteris* as well as that of *Alethopteris*, possesses the *Myeloxylon* type of stem structure. The Meduloseæ to which *Myeloxylon* belongs are regarded as a divergent branch of the Cycadofilices.† The only information regarding the fructification is that obtained by Kidston from a specimen of *N. heterophylla*, a species of the small-pinnuled division of the group.‡ Kidston's material was unfortunately poorly preserved, but served to indicate that the fronds were dimorphic, and that the spore-bearing organs were grouped in clusters at the ends of the slender petioles. There is reason for believing that the entire Neuropterid group was dimorphic. As a rule, those plants having the sporangia on the under side of the fronds, after the manner of ordinary ferns, not infrequently preserve impressions of the sporangia and sori. *Neuropteris* is abundant throughout the Coal Measures, and very large collections of Neuropterid fronds have been examined by various paleontologists without finding evidence of sporangia. The large fronds of *Neuropteris* would doubtless supply a considerable number of detached pinnules as compared with the number of fertile spore-bearing parts, however these may have been arranged. In the Yale University Museum collection, the proportion between *Codonotheca caduca* and *Neuropteris decipiens* is approximately one of the former to ten of the latter.§ Nevertheless, the fact should not be lost sight of that there are a number of other plants in the Coal Measures to any one of

*Renault, Affinités botaniques du genre *Neuropteris*, Comptes rendus, vol. lxxxiii, pp. 399–401, 1876.

†Scott, Studies in Fossil Botany, pp. 394–396. Compare also Solms-Laubach, Über *Medulosa Leuckarti*, Bot. Zeitung, Bd. lv, Heft x, pp. 175–202, 1897.

‡Trans. Roy. Soc. Edinburgh, vol. xxxiii, pt. i, p. 150, pl. viii, fig. 7, 1887.

§ The relative proportion, as here given, is based on the Yale collection from Mazon Creek, which contains 75 specimens of *Codonotheca* to some 1,200 of *Neuropteris*, 750–800 of which are *Neuropteris decipiens*.

which the fructification here described may belong, or that it may represent an entirely new plant.

My thanks are due Dr. Alexander W. Evans for references to recent botanical literature, and to Dr. David White and Dr. G. R. Wieland, as well as to Dr. Evans, for suggestions on the text and illustrations. Dr. E. R. Cumings has very kindly made most of the drawings. The material on which the study is based is contained in the fossil plant collection of Yale University Museum, made accessible to me through the kindness of Professor C. E. Beecher.

Paleontological Laboratory, Yale University Museum,
New Haven, Conn., April 2, 1902.

EXPLANATION OF PLATE.

PLATE VIII.

Codonotheca caduca gen. et sp. nov.

FIGURE 1.—The fleshy covering has disappeared from this specimen by maceration, allowing the resistant area at the center, which still retains its cylindrical shape, to stand out prominently. Strands I to III and VI are visible, IV and V being hidden on the opposite side. Figure 11 is a photographic reproduction of a part of the same specimen with the covering removed, exposing strands IV and V. ×2.

FIGURES 2–3.—Obverse and reverse sides of a small specimen. The very numerous large spores lie in a depressed channel along the segments from the tip to the base. The cavity formed by the united bases of the segments ends at *c*. A part of the upper side of the covering is broken away near the bottom, allowing the spores to be seen within. The base of this specimen, as preserved, is comparatively slender and is traversed by wavy lines. A considerable part of the long slender petiole is preserved. Natural size.

FIGURE 4.—The two bundles supplying the segment, and their origin from two adjacent main strands below, are very well shown in this specimen. Natural size.

FIGURE 5.—Plan of structure of the spore-bearing organ. The top is represented as cut open and unrolled, the base as split down the center and laid open. The cut is represented as passing between segments I and VI, hence directly through strand number I. The end of the cavity is marked at *c*. The cylindrical area at the base first breaks up into six main strands (I to VI) which dichotomize and supply the twelve bundles to the spore-bearing divisions. Natural size.

FIGURE 6.—A group of spores imbedded in sphalerite, and having the surface ornamentation well preserved. ×28.

FIGURE 7.—Spores taken from the surface of the specimen illustrated in figure 2. ×28.

FIGURE 8.—A single spore; showing the slit in the side, indicating probably the bilateral division of the spore mother-cell. Several dark bodies, apparently representing stored food supply, are contained within the spore. ×85.

FIGURE 9.—Section through the spore wall; showing a thick granular outer, and a thin compact inner layer. ×200.

FIGURE 10.—The specimen illustrated by this figure has suffered lateral crushing, and the bundles are partly displaced. A few spores are still clinging to the surface. Natural size.

FIGURE 11.—Same specimen as figure 1. ×2.

FIGURE 12.—Photograph of a small specimen. The first segment on the right is seen from the dorsal surface, showing the parallel striæ. The next segment is seen from the ventral (inner) side. The two strong bundles traversing this segment can be traced in the photograph. The origin of these two strands from alternate strands below, which can be distinguished only by close scrutiny in the photograph, is very evident in the specimen. The outline of the resistant area formed by the union of the bundles below can be followed by its white micaceous coating such as often covers the fossils in these nodules. Natural size.

FIGURE 13.—The large base is here flattened. The striæ of the base are more or less disarranged and have a wavy course. Some of them seem to divide, and all converge to the point of attachment. The photograph also shows the cone-shaped resistant area at the center, which is large above where it breaks up into strands; pointed below. The first spore-bearing segment on the left is crushed, giving it an unnatural width. At the top of the next one is seen the dorsal surface marked by fine striæ. Farther down the segment is removed, leaving the impression of the ventral (inner) surface on which the two bundles supplying the segment are seen. At one point about half-way down, the break extends through to the opposite side of the organ and a few spores are seen in place on the opposite surface. Natural size.

FIGURES 14–15.—A specimen worked out so as to expose both sides of the organ. The base of this specimen is not entirely flattened, having partly retained its shape. The side illustrated in the pen drawing, figure 15, shows for the most part the impression (mold) of the outside surface. In places, however, the substance of the plant has clung to the mold. This is true of a part of the vascular system, and the tips of segments VI and I, giving an instructive view of the ventral (inner) surface. The two bundles are distinct, lie near the surface, and are rather widely separated. The segments have considerable thickness as seen in the break, being perhaps half as thick as wide. The impression made by the dorsal surface is longitudinally striate, as seen in the other segments of this and other specimens. The dorsal surface of the segment itself is represented in figure 17, showing the parallel striæ, and the minutely roughened or pitted surface. The photograph of the opposite side as it lies in the nodule, figure 14, gives a partial dorsal view of segments I and IV, which are crushed laterally and distorted. Segments II and III have retained their shape and are seen from the ventral (inner) view. The cone-shaped portion of matrix which originally filled the center of the organ is preserved in the Yale collection, and shows on one side, corresponding to the side from which the photograph was made, the impressions of the ventral side of the segments; while on the other side, that from which the mold serving as the basis of figure 15 came, the dorsal surface of the segments (except the tips of VI and I) are seen. Natural size.

FIGURE 16.—Enlarged detail of the petiole; showing the strong striæ and weaker cross lines. ×3.

FIGURE 17.—Enlarged detail of dorsal surface of the segment. ×3.

FIGURE 18.—An average specimen. Natural size.

Art. X.—*Note on the Dates of Publication of Certain Genera of Fossil Vertebrates;* by Lucy P. Bush.

Several years ago while carrying on bibliographic work under the direction of the late Professor Marsh, personal search resulted in the acquisition of exact data relating to the generic names of certain vertebrates, the use of which by various authors is not uniform. In the interest of science, it seems wise to give these facts publicity. The object of the present note, however, is not to decide whether the vertebrate fossils in question should be classed under a given genus; it is merely to show which term has priority, leaving the subject of synonymy to others more competent to judge in such matters.

Cardiodon and *Cetiosaurus.*

Cardiodon Owen, April, 1841, Odontography, vol. i, pt. ii, p. 291.
Cetiosaurus Owen, 1841, Proc. Geol. Soc. London, for June 30, vol. iii, pt. ii, No. 80, p. 460.

The dinosaurian genus *Cardiodon* was founded by Owen in 1841, on "an almost heart-shaped form of tooth" (*Odontography*, vol. i, pt. ii, p. 291). The work in which the name first occurs was published in three sections, and the second part, containing the paragraph relating to *Cardiodon*, appeared between April 15 and May 1, 1841.* As the paper in which

*The Publishers' Circular, London, notes the date of publication of each part of Owen's Odontography, as follows:—

Part I (Dental System of Fishes, pp. 1–178), between March 16 and April 1, 1840 (see Circular for April 1, 1840, vol. iii, p. 96).

Part II (Dental System of Reptiles, pp. 179–295), between April 15 and May 1, 1841 (ibid. for May 1, 1841, vol. iv, p. 116).

Part III (Dental System of Mammals, pp. 296–655), before March 2, 1846 (ibid. for March 2, 1846, vol. ix, p. 80; and The English Catalogue of Books published from January, 1835, to January, 1863, p. 577, 1864).

The foregoing work was issued in two editions—a quarto edition in two volumes and a royal octavo edition in two volumes. Copies of both these editions are in the library of Yale University Museum, and the pagination, numbering of plates, etc., are identical in the two. The dedication is dated June 18, 1845; the title page, preface, and table of contents were undoubtedly printed when the work was completed, while the introduction may have been in part published at the same time as the third and last section (Circular, vol. ix, p. 80), although some of it appeared earlier, as shown by the following statement taken from The Life of Richard Owen (vol. i. p. 181, 1895):—"On April 27 [1841], as the diary shows, the Introduction was printed."

Each of the 168 plates constituting vol. ii of Odontography is dated at the bottom. Those accompanying Part I (Plates 1–61, 62*B*) bear the date 1840. The plates in Part II (Plates 62–75*a*, exclusive of 62*B*) are dated as follows: Plates 62, 62*A*, 63, 64–66, 68, 70–75, 1840; Plates 63*A*, 63*B*, 67, 69, 1841, and Plate 75*a*, 1844. In Part III (Plates 76–150), Plates 77–79, 81–84, 87, 91–93 are dated 1840; Plates 76, 80, 85, 86, 89, 89*A*, 94, 1841; Plates 87*a*, 101, 106, 129, 130, and 143, 1844, while Plates 90, 95–100, 102–105, 107–128, 131–142,

the genus *Cetiosaurus* was proposed was not read until June 30, 1841 (Proc. Geol. Soc. London, vol. iii, pt. ii, No. 80, pp. 457–462), it is evident that *Cardiodon* may be justly given precedence in time.

Figures of the tooth representing the latter genus are shown in *Odontography*, Vol. II, Plate 75*a*, figure 7, *a–d*. The legend at the bottom of this plate states that the latter was "published by H. Baillière, 1844." In the explanation to the plate (loc. cit., p. 20), the specific name *Cardiodon rugulosus* is proposed. Four species of *Cetiosaurus* were named and described in the Report of the British Association for 1841, pp. 94–102, London, 1842. In the case of neither genus, however, were any species noted in the original description.

Entelodon and *Elotherium*.

Entelodon Aymard, 1846, Ann. Soc. d'Agric., Sci., Arts et Commerce du Puy, tome xii, for 1842–1846, p. 227, 1 planche. Reprint, p. 1, 1 planche, 1848.

Elotherium Pomel, 1847, Bull. Soc. Géol. France (2), vol. iv, p. 1083.

In April, 1894, Professor Marsh prepared a paper on the *Restoration of Elotherium*, and in looking up the literature previous to publication it was found that much confusion existed in regard to the early nomenclature of the group. Few, if any, authors have recognized the fact that the suilline genus *Entelodon* (Ann. Soc. d'Agric., Sci., etc., du Puy, vol. xii, 1846) is prior in date to *Elotherium* (Bull. Soc. Géol. France (2), vol. iv, 1847), Aymard's paper on the former being almost invariably quoted as 1848. Before Professor Marsh's article was printed no data were obtained of sufficient accuracy to warrant the adoption of *Entelodon*, yet facts were subsequently acquired proving that *Elotherium* should be assigned a second place.

Through the courtesy of Baron de Vinols, President of the Society of Agriculture, Science, etc., at Puy, and recently of M. Léopold Delisle, General Administrator of the National Library of Paris, it has been learned that Vol. XII of the Annals of the Puy Society, containing Aymard's paper, was printed by Gaudelet at Puy, in 1846. In his letter on this subject, Baron de Vinols states: "Ce qui a pu faire confondre la date de 1846 avec celle de 1848 c'est que cette dernière date est sur

144–150 were printed in 1845. Plates I and II published with Part III are general and are dated 1845.

The facts given in a note by W. H. Brown (Woodward and Sherborn's Catalogue of British Fossil Vertebrata, London, 1890, p. xxix) do not coincide with those here stated.

la couverture extérieure du livre et la dâte de 1846 est dans l'intérieur."

In the library of the Yale University Museum, there is a perfect reprint of Aymard's original article (pp. 1–45), also printed by Gaudelet at Puy. On the title page of this extract the year 1848 appears, indicating that separate copies were not published until two years later than the volume of Annals containing the original description of *Entelodon*.

Two species, *Entelodon magnus* and *E. Ronzonii*, are defined by Aymard in his original paper; the former is regarded as the type, and is figured in the plate (figures 1–4) accompanying the article.

Bothriodon, *Ancodus*, and *Hyopotamus*.

Bothriodon Aymard, 1846, Ann. Soc. d'Agric., Sci., Arts et Commerce du Puy, tome xii, pp. 239, 246 (note). Reprint, pp. 15, 22 (footnote), 1848.
Ancodus Pomel, 1847, Arch. Sci. Phys. Nat., Genève, tome v, p. 207.
Hyopotamus Owen, 1848, Quart. Journ. Geol. Soc. London, vol. iv, p. 104, pls. vii, viii.

The argument relating to the genus *Entelodon* likewise applies to the name *Bothriodon*, the latter having been proposed by Aymard in Vol. XII of the Annals of the Society at Puy, in 1846. In regard to the genera *Ancodus* and *Hyopotamus* Dr. O. P. Hay in his recent *Bibliography and Catalogue of the Fossil Vertebrata of North America* (Bull. U. S. Geol. Surv., No. 179, p. 652, 1902) states that *Ancodus* antedates *Hyopotamus*. It will be seen, however, that *Bothriodon* has claim to priority over both the other genera.

In his original paper, Aymard proposes two species of *Bothriodon*, which he regarded as a subgenus: "l'une, *à museau très large* [*botriodon platorynchus*]; l'autre, *à museau étroit* [*bot. leptorynchus*]." He further states: "Il y en a une troisième beaucoup plus petite, qui pourra conserver le nom de *velaunus*, imposé par Cuvier à l'espèce type."

The data here presented led Professor Marsh to adopt the use of the generic names *Cardiodon* (Cetiosaurus),* *Entelodon* (Elotherium),† and *Bothriodon* (Ancodus, Hyopotamus), although the last term has not his sanction through publication.

Paleontological Laboratory, Yale University Museum, June 1, 1903.

* This Journal (3), vol. i, p. 496, December, 1895; The Dinosaurs of North America, 16th Ann. Rept. U. S. Geol. Surv., p. 242, 1896.

† Johnson's Universal Cyclopædia, vol. viii, p. 498, fig. 47, 1895; Vertebrate Fossils of the Denver Basin, Mon. U. S. Geol. Surv., vol. xxvii, pp. 522, 523 (fig. 97), p. 548, and pl. xxx, 1897.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Spinthariscope.*—In connection with a discussion of certain properties of radium emanations, Sir William Crookes describes a striking phenomenon produced upon the zinc sulphide screen by the heavier, non-deflectable, positive atoms emitted by radium. He says: "If a solid piece of radium nitrate is brought near the screen, and the surface examined with a pocket lens magnifying about 20 diameters, scintillating spots are seen to be sparsely scattered over the surface. On bringing the radium nearer the screen the scintillations become more numerous and brighter, until when close together the flashes follow each other so quickly that the surface looks like a turbulent, luminous sea. It seems probable that in these phenomena we are actually witnessing the bombardment of the screen by the positive atoms hurled off by radium with a velocity of the order of that of light: each scintillation rendering visible an impact on the screen, and becoming apparent only by the enormous extent of lateral disturbance produced by its impact. Just as individual drops of rain falling on a still pool are not seen as such, but by reason of the splash they make on impact and the waves they produce in ever widening circles."

The spinthariscope, devised for observing this phenomenon, consists of a brass tube with a blende screen at one end of it which has a speck of radium salt in front of it and about a millimeter off, and a lens at the other end which can be accurately focussed upon the screen.—*Chem. News*, lxxxvii, 241. H. L. W.

2. *Properties of Sodium Sulphate Solutions.*—It is well known that sodium sulphate with ten molecules of water of crystallization is deposited from solutions below 32·38°, while the anhydrous compound is formed at higher temperatures. No evidence has been obtained heretofore that water combines with sodium sulphate while the latter is in solution. Marie and Marquis have, therefore, undertaken the investigation of this question by a new method. They determined the solubility of sodium chloride in a given solution of sodium sulphate at temperatures varying from 14·8° to 34·28°. It was expected that a sudden change in the solubility would occur if at some point the sodium sulphate molecules formed a combination with water. No such sudden change was observed, for the results when plotted gave a perfectly regular curve. Consequently, there is no reason for supposing that the salt with ten molecules of water exists in solution.—*Comptes Rendus*, cxxxvi, 684. H. L. W.

3. *Radio-active Lead.*—About two years ago Hofmann and Strauss announced the preparation of radio-active salts from the lead obtained by the usual chemical methods from various minerals containing uranium and thorium. Hofmann and Wölfl

have recently described further investigations in regard to this matter. They are convinced that this substance is an independent radio-active principle, and that it is distinct and separable from ordinary lead, although standing close to that metal in its chemical properties. The interesting fact was observed that solutions of radio-active lead are capable of inducing very great activity in metals which are placed for a long time in contact with them, but upon which they exert no chemical action, for instance platinum, gold and silver palladium, and particularly iridium. The metals remain perfectly bright under these circumstances; the activity, which is often greater than that of the original substances, is not removed by washing with water or by rubbing with paper, but it is quickly lost by ignition in most cases. The theory is advanced that the α radiation (the less penetrating kind, following Rutherford's designation) is a finely-divided kind of matter the particles of which, like hydrogen, are occluded by metals.—*Berichte*, xxxvi, 1040. H. L. W.

4. *Colloidal Silver.*—Some observations upon Carey Lea's colloidal silver have been made recently by Hanriot. The work was done with a commercial form of the substance which is sold in France as a therapeutic agent under the name of *collargol*, and which corresponds to Lea's first modification of colloidal silver. It was found that solutions of this substance, upon being submitted to electrolysis, deposit silver upon the positive electrode, whereas metals are deposited from solutions of their salts upon the opposite pole. This and other properties of the solutions have led this investigator to the conclusion that colloidal silver is the salt of an acid to which he gives the name "collargolic acid." This acid is evidently composed largely of silver, and it is energetic enough to displace carbonic acid. The black deposit upon the positive electrode which has been taken for silver is not ordinary silver but collargolic acid, for, while it is insoluble in water, it dissolves in alkalies and alkaline carbonates, forming red solutions. The author believes that this acid is combined with ammonia in the original substance, and he proposes to make a further study of the matter.—*Comptes Rendus*, cxxxvi, 690.

H. L. W.

5. *The Iodides of Caesium.*—The iodides CsI_3 and CsI_5 were described by Wells and Wheeler in this Journal in 1892. H. W. Foote of the Sheffield Scientific School, using theoretical considerations which are mainly based upon the phase-rule of Gibbs, and employing chiefly solubility determinations, has found that the periodides mentioned are the only ones existing between $-4°$ and $73°$. The method employed appears to be novel in its application, and it will doubtless be very useful when applied to the study of other complex compounds, particularly of double-salts.—*Amer. Chem. Jour.*, xxix, 203. H. L. W.

6. *Quantitative Chemical Analysis by Electrolysis;* by Alexander Classen. Translated, revised, and enlarged by Bertram B. Boltwood. 8vo, pp. 315. New York 1903

(John Wiley & Sons).—In preparing the fourth English edition of this well-known and valuable book, the translator has made important additions to the last German edition by making use of Classen's "Ausgewählte Methoden der Analytischen Chemie" and other recent publications. The book, containing, as it does, the most recent methods, improved illustrations, and full references to the literature of the subject, is to be highly recommended to those who are interested in this branch of analytical chemistry.

H. L. W.

7. *Chemisches Praktikum;* von Dr. A. Wolfrum. II Theil, Präparative und Fabrikatorische Uebungen, 12mo, pp. 580; mit einem Atlas (4to, pp. 156 and 11 plates). Leipsic 1903 (Wilhelm Engelmann).—The first volume of this excellent work was noticed in vol. xiv of this Journal. The present part deals with a large variety of chemical preparations, and the plan of giving the student a knowledge of factory operations is well carried out. The atlas contains a large number of interesting cuts, chiefly of apparatus used in chemical manufacturing. H. L. W.

II. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have recently been received:

Bulletin No. 213.—Contributions to Economic Geology, 1902. S. F. Emmons, C. W. Hayes, Geologist in Charge. This bulletin was prepared in order to secure a prompt publication of the economic results of recent investigations by the United States Geological Survey. The volume is divided into two main divisions, one under the editorship of Mr. Emmons treating of metalliferous mineral deposits and the other under the editorship of Mr. Hayes of the occurrence of nonmetalliferous economic minerals. It includes some 61 different contributions from 33 members of the Survey. The papers represent three classes: (1) Preliminary discussions of the results of extended economic investigations which will later be published in more detailed form; (2) Comparatively detailed descriptions of occurrences of economic interest but not of sufficient importance to necessitate a later and more extended description; (3) Abstracts of certain economic papers of a general nature which have appeared in Survey publications during the year. W. E. F.

Oelrichs Folio, South Dakota, Nebraska; by N. H. Darton.—The Oelrichs quadrangle covers an area on the eastern edge of the Black Hills and contains features of the Black Hills proper, of the hogback rim and of the great plains. The sedimentary record deals with strata from late Carboniferous to recent. The simplicity of geologic structure exhibited in this region makes the folio of great educational value.

Water Supply and Irrigation Papers: No. 73.—Water Storage on Salt River, Arizona; by A. P. Davis. 52 pp., 25 pls., 4 figs.

No. 75.—Report of Progress of Stream Measurements, 1901; by F. H. NEWELL. 231 pp., 13 pls., 71 figs.

No. 76.—Observations on the Flow of Rivers in the Vicinity of New York City; by H. A. PRESSEY. 104 pp., 13 pls., 8 figs.

2. *New York State Museum.* BULLETIN No. 56 (Geology 5).—Description of the State Geologic Map of 1901; by F. J. H. MERRILL. 34 pp. An account of geologic mapping in New York State from 1820 to 1900 and the authorities for the map of 1901 are given. In the map itself a distinct advance is made over the Preliminary Geological Map of New York published in 1894, by the addition of topographical facts furnished by the folio sheets of the United States Geological Survey, and by the discrimination of boundaries, developed since that date. A list of thirty-three contributing geologists is given whose detailed work in the several counties of the State has been incorporated in the revised map.

The chief areas in which changes appear are the Pleistocene geology of Long Island, the igneous and pre-Cambrian geology east of the Hudson and about the Adirondacks, the Lower Paleozoics of the latter region and the Devonian of the central and southern portion of the State. The map is drawn on the same scale as the 1894 map, viz: 2½ miles to the inch.

Some confusion still exists in the mapping of the Devonian formations. The Catskill-Chemung boundary of the eastern part of the State is evidently drawn on the theory that its lower base is at a relatively higher stratigraphic position on passing westward, while the corresponding upper limits of the underlying rocks are at relatively higher horizons passing in the same direction. This is not a case of unconformity, but of change in the character of the sediments similar to the changes occurring in the Niagara, which is more calcareous to the westward, and the Lower Helderberg limestone, which as a limestone is confined mainly to the eastern half of the State. In other cases (viz: the Genesee shale, the Tully limestone, the Onondaga limestone, etc.) a similar fact is expressed by narrowing out the line of outcrop to nothing or nearly nothing. These are strictly expressive of distribution of formations, the definition of formation being based on uniformity of lithologic characters. In the case of the Portage, Ithaca and Oneonta formations, an attempt is made to express differences in the fossil contents of formations occupying the same stratigraphic interval. The confusion in this case arises from the attempt to express two kinds of facts (distribution of faunas and distribution of formations) with a single set of symbols. Thus when the Portage and Ithaca formations are represented by an abrupt change in the color scheme, between Cayuga and Seneca Lakes, the fact that the boundaries of the formations are continuous shows that the change is not in the formations but in the fossils.

Although the writer is well aware of the important facts here indicated, he continues to believe that no advantage will be

gained by confusing on a geological map the distribution of fossil faunas with the distribution of geological formations which the map purports to represent.

In the text accompanying the map the State geologist has contributed an interesting and valuable detailed exhibit of the historical development of the nomenclature of the New York State geology. Among other things suggested by its examination is the real significance and naturalness of the subdivisions proposed by Mather in his report of 1840. The *Catskill, Helderberg, Ontario,* and *Champlain* series express natural divisions of the New York system, which is in great measure lost sight of in the later attempts to adjust the classification to the European scheme. As the details of our geology are developed, the grander episodes in the sedimentation of each geological basin should be emphasized rather than warped to fit any universal scheme of classification. A correct representation of the facts is far more important than uniformity of classification or nomenclature. H. S. W.

3. *Geological Survey of New Jersey,* HENRY B. KÜMMEL, State Geologist; Report on Paleontology, vol. iii. The Paleozoic Faunas; by STUART WELLER, 462 pp., 53 pls.—Professor Weller has presented a clear and concise account of a section of the Paleozoic in the State next adjoining New York which presents many features quite distinct from that long-time standard.

The sections fall into three quite distinct groupings in the three areas of the Delaware Valley, Kittatinny Valley and Green Pond Mountain region. In the first the Cambrian and Ordovician are wanting—the Silurian and Devonian having full complement of formations. The reverse is the case in the second area, and the Ordovician and much of the Silurian and Devonian are missing in the third.

The Hardyston quartzite holds the Olenellus fauna. The Kittatinny limestone, 2700 to 3000 feet in thickness, has a fauna resembling the Upper Cambrian fauna of Minnesota and Wisconsin and in its upper part carries Ordovician species. The Trenton limestone carries a Black River fauna below and pure Trenton fauna above; but not the highest fauna of the New York section: it is 135 to 300 feet thick and runs up gradually into a typical Hudson River slate. The Norman's Kill shale fauna appears near the base of the Hudson River. The Shawangunk conglomerate lies unconformably upon the latter, and reaches a thickness of 1500 to 1600 feet. Above this is the Medina (Longwood) sandstone, over 2300 feet thick. These are supposed to represent the Oneida and Medina of New York, though no fossils have been seen. Then follow, in the Delaware Valley, the Poxino Island shale, the Bossardville limestone, Decker Ferry formation, Rondout formation, and the Manlius limestone. The Decker Ferry formation is correlated directly with the Coralline limestone of New York. The Rondout contains almost exclusively Leperditia, and *Leperditia alta* is in both it and the following Manlius, which is the Spirifer vanuxemi zone.

The Coeman's limestone contains the Gypidula gaſeata fauna and is placed as the first of the Devonian formations. It is followed by the New Scotland, Stormville, Becraft, Kingston, Oriskany, Esopus and Onondaga limestone. We note that the author concludes that "a careful study of the Helderberg and Oriskany faunas of New Jersey has brought out conspicuously the absence of any sharp dividing line between these two horizons either of a stratigraphic or of a faunal nature" (p. 96).

The Newfoundland grit, which follows in the Green Pond Mountain region, contains a fauna essentially that of the Onondaga limestone, without the mixture of Oriskany species, which was stated erroneously to be the case in the preliminary report. The Monroe shales (700 to 1000 feet thick), as well as the following Bellevale flags (1800 feet), contain the Tropidoleptus carinatus fauna with no admixture of Chemung species.

The Skunnemunk conglomerate alternating with red sandstone follows without observed fossils and terminates the Paleozoic series of the State. A considerable number of new species are described. H. S. W.

4. *Maryland Geological Survey:* Wm. Bullock Clark, State Geologist: Volume IV, 1902, 524 pp, 34 figs., 49 pls., including Part I, Paleozoic Appalachia, or the history of Maryland during Paleozoic time, by Bailey Willis (pp. 23–91). Part II, Second Report of the Highways of Maryland, by Harry Fielding Reid and A. N. Johnson (pp. 95–179). Part III, Report on the Clays of Maryland, by Hendrick Ries (pp. 203–503).

Cecil County, 322 pp., 24 figs., 30 pls., and Atlas including chapters on the physical features, the physiography, the geology, the mineral resources, the soils, the climate, the hydrography, the magnetic declination and the forests of Cecil county, each one prepared by scientific experts.

Garrett County, 340 pp., 13 figs., 26 pls., and Atlas. This Report gives full details regarding the special physical and geological features as is the case of Cecil county.

In the first volumes there are combined an interesting discussion of the changes the underground basis of the State has supposedly undergone in past geological time which must stand on a highly theoretical basis, with the thoroughly practical and economic problems connected with modern roads and the brick industry. The county reports are made as attractive and interesting as scientific reports can be made by applying the skill of experts to the interpretation of each section of the physical phenomena examined, treating each subject so as both to bring out the new scientific facts and to artistically explain them; and, throughout, the State geologist has succeeded in weaving into his reports those practical qualities which are so highly appreciated by the general public for whom they are primarily prepared. H. S. W.

5. *Geography and Geology of Minnesota.* Volume I. Geography of Minnesota; by C. W. Hall. 287 pp., 5 pls., 163 figs. Minneapolis (The H. W. Wilson Company).—The natural features of Minnesota are so varied as to illustrate nearly every

elementary principle of Physiography, and Professor Hall has done his state a service in calling attention to its wealth of natural scenery. Explanations of the peculiar drainage systems and numerous lakes are particularly interesting.

6. *Plumasite, an oligoclase-corundum rock near Spanish Peak, Cal.*; by A. C. LAWSON. Bull. Geol. Dept. Univ. Cal., vol. 3, No. 8, 1903, pp. 219–229.—The author comments on discoveries made during recent years, which show that corundum is a not uncommon constituent of igneous rocks, and then describes an occurrence in which it is an essential constituent of the rock of a dike cutting a belt of peridotite on the lower east flank of Spanish Peak in the Sierra Nevada. The dike is about 15 feet wide composed of a white rock made up of feldspar, which varies from coarse to fine and which was determined to be oligoclase. In places this is found to carry considerable corundum in imperfectly formed violet-blue crystals. In the specimens examined the corundum made up 16 per cent of the rock, the remainder being oligoclase. For this type the name of *plumasite* is proposed from Plumas Co., Cal., in which it occurs.

An investigation of the peridotite was made and the results of this are also given. L. V. P.

7. *An Experimental Garden in Cuba.*—Three years ago, Mr. E. F. ATKINS, of Boston, who has extensive interests in Cuba, placed at the disposal of the Botanic Garden of Harvard University such land, labor, materials, and money, as might be required for a small experimental station for the study of certain tropical plants in their economic relations, especially with the view to improvement in their yield and quality. Arrangements were completed by which the more important tropical plants adapted to the climate of southern Cuba, were obtained in abundance both as regards number and variety. A large collection of sugar-canes was secured from a very wide geographical range, and these were placed at once under conditions favorable for attempts at crossing. It is well known that almost all varieties of sugar-cane, now in cultivation, bear only very imperfect flowers which are practically incapable of impregnation without artificial aid. The interesting experiments in Java and elsewhere have shown that by intervention at the right time, it is possible in some cases to secure good seed sparingly, and from these few seeds to obtain varieties which are decidedly promising as regards content of sugar, vigor of growth, and resistance to hurtful influences. The aid of Mr. R. M. Grey, the well known hybridizer, was secured for this work upon cane, and he had access to all the varieties in stock. One very successful result was the production of a strong variety which encourages to further effort. Some doubt was felt at first whether the climatic conditions in Cuba were favorable for the early stages of crossing, but these doubts have been largely dissipated by even the moderate success which Mr. Grey obtained. A good many of his seedlings were not properly cared for by one of the station hands, and were lost shortly after Mr. Grey returned north.

Last year it was decided to obtain from Mexico a good supply of the economic plants most favorably known in that country, and to cultivate them in the grounds of the station. The management was so fortunate as to obtain the services of Mr. C. G. Pringle, the botanical collector, who is thoroughly conversant with the most desirable sources of Mexican supply. His work was exhaustive and thoroughly satisfactory in every respect. The plants were shipped directly across the Gulf, and were received in good condition. The collection now at the Station is ample for a wide series of crosses and selections.

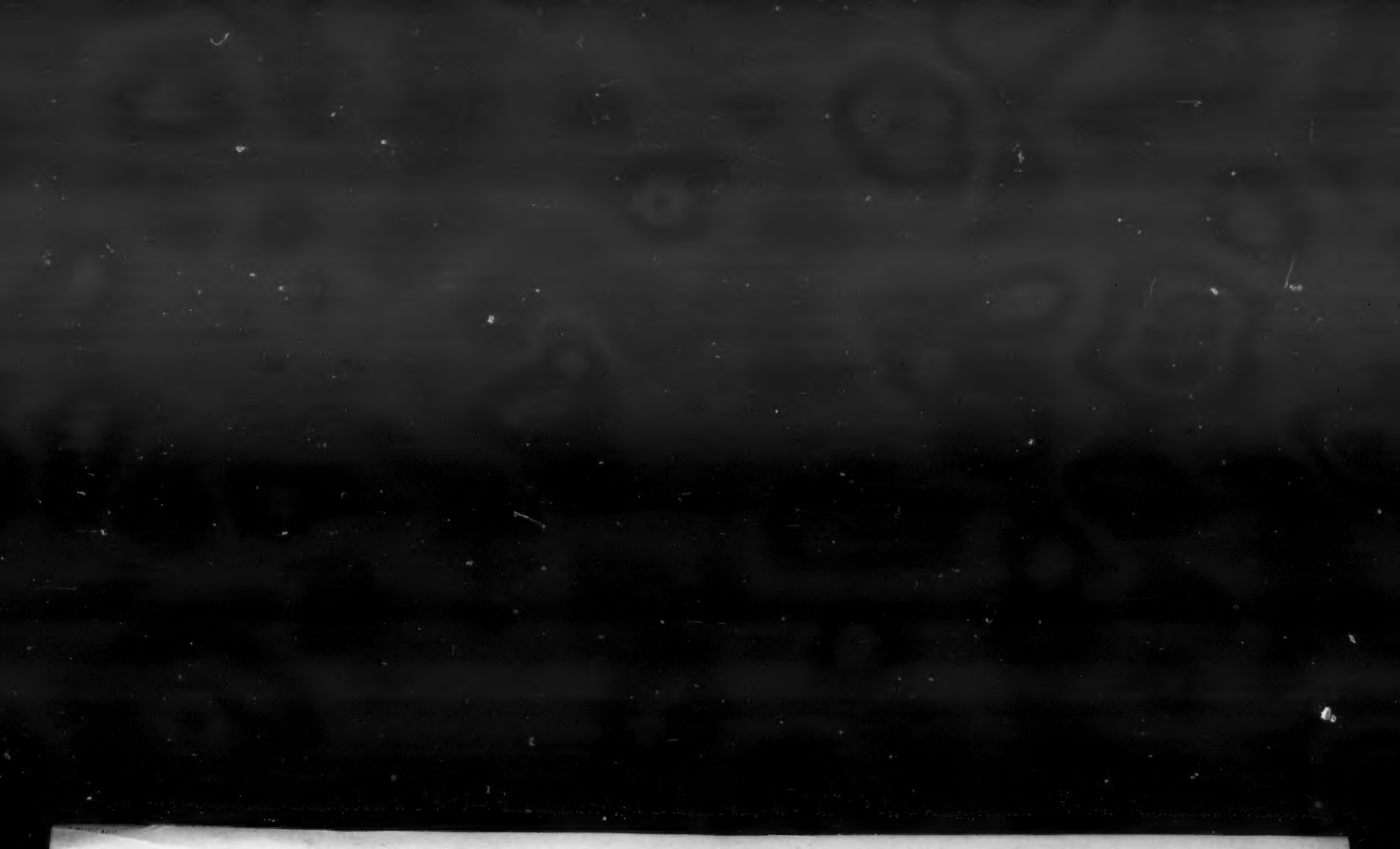
Among the plants which had appeared to be desirable for extensive experiments was cotton in its different varieties. It soon became apparent, however, that this plant is confronted in Cuba by its most implacable enemy, the cotton-ball worm. From all the experiments upon this plant at the Station, it is plain that large plantings in the island are sure to be attended with the most complete failure until means can be devised to check the mischief done by this insect. G. L. G.

III. Miscellaneous Scientific Intelligence.

1. *United States Coast and Geodetic Survey.* O. H. Tittman, Superintendent, Annual Report 1902. 787 pp., 68 plates and maps.—The details of the Coast Survey work from July 1, 1901, to June 30, 1902, show gratifying progress in all its branches. The progress of the work in the Philippine Islands is especially noticeable. In addition to reports on the regular work of the Survey, there are two appendices of timely value: one by W. D. Alexander on Hawaiian Geographic Names (pp. 373–424), the other by J. Howard Gore on a Bibliography of Geodesy (second edition).

2. *National Bureau of Standards.*—In Circular of Information, No. 3, S. W. Stratton, Director, explains the present facilities for comparison of standards. Comparison may now be made of length and capacity measures, weights, polariscopic apparatus, hydrometers, thermometers, photometric standards, and electrical instruments.

3. *The Scientific Writings of George Francis Fitzgerald.* Edited by Joseph Larmor. xlv + 569 pp. London (Longmans, Green & Co.).—In making a collection of Professor Fitzgerald's writings "an endeavor has been made to include everything substantial of a scientific character that he wrote." One hundred and eight essays are here reproduced and the editor has added a biographical and historical introduction.

Obituary.

Professor J. Peter Lesley, the eminent geologist, whose lifelong labors contributed so much to our knowledge of the Pennsylvania Coal-measures and of the structure of the Appalachians in general, died at Milton, Mass., on June 1, aged eighty-three years.